HONI SOIT QUI MAL Y PENSE

PREFACE.

WHEN the Geological Survey, in its northward progress from the midland counties of Scotland, entered upon the examination of the Southern and Eastern Highlands, many difficulties were encountered in the attempt to ascertain and map the true order of succession of the rocks of that part of the country, and the details of their tectonic arrangement. The further the field-work was carried into the region of the crystalline schists the problems which these schists presented seemed to increase in number, and the prospect of being able to solve them appeared to grow more distant. Accordingly I at last came to the conclusion that as a recognisable succession of formations had long been known to exist in the North-West Highlands, more satisfactory progress would not improbably be made if a portion of the surveying staff of the service were transferred to that region.

In the hope, therefore, that a detailed study of Western Sutherland and Ross would throw light on the geological structure of the rest of the Highlands, a beginning was made in the year 1883 in the district of Durness by Messrs. Peach and Horne. The history of the previous investigation of the geology of the North-West Highlands will be found fully narrated in Chapter II. of the present volume. It will be sufficient to remark here that when the Geological Survey entered upon the detailed examination of the ground it was in the expectation that the stratigraphical sequence which had been worked out by Murchison, from the fundamental gneiss up into the "gneissose flagstones" or "Eastern schists," would be established by more minute study. But this anticipation was soon dispelled. The structure of that north-western portion of Scotland was found to be infinitely more complex than had been supposed. In particular the "Eastern schists" which Murchison believed to lie conformably upon the fossiliferous Durness limestones were found to have been pushed into their present position by gigantic dislocations of the terrestrial crust. Thus what had been assumed to be a conformable sequence from the older Palæozoic limestones into an overlying series of schists proved to be entirely deceptive.

In these circumstances no fresh light could, in the meantime, be expected to be thrown on the problems of the structure and age of the crystalline rocks of the Highlands by prosecuting the mapping eastward into the great region of the gneissose flagstones, for the very same difficulties there presented themselves which had been found insuperable in the southern and eastern parts of the Highlands. But the detailed examination of the north of Sutherland had brought to light some types of tectonic structure of a kind and on a scale such as had never before been met with in any portion of the British Isles. It was discovered that by a complicated series of reversed faults, combined with stupendous horizontal thrusts, the rocks had been pushed over each other, slice after slice, huge sheets of the very oldest masses having been torn up and driven westward for miles so as to rest now upon the younger groups. Fortunately, owing to the marked contrast in lithological characters between the three great series of rocks —the grey or pink fundamental gneiss, the red Torridon sandstone, and the white quartzites with the limestones and dolomites —it was possible to trace the severed portions of these several formations, even through extremely complicated structures. Having regard therefore to the ultimate solution of the Highland problems which had hitherto baffled us, I deemed that our wisest course would be to follow southward the band of territory in which these novel tectonic features had been encountered and to map it thoroughly to its extreme limits. By unravelling the complications of that piece of ground, and watching the variations in their development from district to district, it might eventually be possible to obtain a clue to the origin, sequence, and structure of the crystalline rocks of the Central Highlands.

As the mapping extended southwards it was found that the new tectonic types were developed in a strip of country which stretches along the west of the counties of Sutherland and Ross from the coast near Cape Wrath for more than a hundred miles to the most southerly promontory of the Isle of Skye. This tract of disturbed ground, or "belt of complication," as it came to be called, is bounded on the east by the most easterly of the great thrust-planes on which the gneissose flagstones, or "Moine schists," have been driven. The mapping was mainly confined to the ground between the outcrop of that thrust-plane and the western coast-line, though here and there a broader tract of the Eastern schists was surveyed.

After five years the work had stretched across the district of Assynt, where the new tectonic types were found to be admirably developed. Enough of information had now been collected regard-and correspondingly redundant in the other. It is obviously hardly possible for an editor, even when fully conversant with the subject, to secure among the essays of variously gifted contributors that degree of uniformity of treatment which he might desire. Considerable excision and condensation were found to be absolutely necessary in the manuscript of the present volume; and perhaps some readers may wish that these alterations had been carried still further. But I trust that no one who shall take the book with him to the ground for the purpose of mastering the structure of what will always be regarded as one of the most instructive of geological regions, will find the superabundance of local details a hindrance.

It may be claimed that the present volume, based upon Ordnance Survey maps on the large scale of six inches to a mile ($\frac{1}{10560}$), contains the first detailed account of the structure, distribution, and petrography of the whole of the Lewisian Gneiss and Torridonian Sandstone of the mainland of Scotland west of the Moine thrust, and that it thus makes an important fresh contribution to our knowledge of the pre-Cambrian rocks of Britain. It likewise records the results of an exhaustive examination of the rocks and fossils of the Cambrian formations of the same region, and in particular shows the distribution and organic contents of the *Olenellus*-zone which the Geological Survey has detected and traced there. But undoubtedly the feature which will give the volume its greatest interest and novelty in the eyes of geologists is the full description and illustration which it contains of the remarkable tectonic structures, the discovery of which has made the north-west of Scotland a classic region for the study of some of the more stupendous kinds of movement by which the crust of the earth has been affected.

While each of the geologists engaged in the survey of the region has contributed an account of the ground which he has himself surveyed, Dr. Horne has also supplied the introductory chapters. The petrographical portions are the work of my successor, Dr. Teall. In the early stages of the field-work some Lewisian rocks were examined and reported on by Dr. F. H. Hatch, while towards the close of the mapping a few rocks were submitted to Dr. J. S. Flett. Dr. Peach, now retired from the service, has furnished the palæontological discussions and descriptions, and to his skilful and artistic pencil the reader is also indebted for the diagrams illustrative of the tectonic structure of the districts of Eireboll, Assynt, Loch Maree, and Loch Carron, which form one of the most important features of the volume. Certain portions of the "belt of complication" were mapped by Mr. H. M. Cadell, Mr. E. Greenly, and Mr. A. Harker, who supplied notes of their work, which have been incorporated in the Memoir. The chemical analyses have been chiefly made by Dr. Pollard; a few have been supplied by Mr. Hort Player, Dr. Teall, and Mr. Barrow. The collecting of the rock-specimens on which the petrographical studies have been mainly based, and of the fossils which have formed the groundwork of the palæontological section, has been done by Mr. Arthur Macconochie, to whose trained eyes the discovery of the *Olenellus*-zone is due. The photographs of landscapes and portions of rock-scenery from which plates have been made were taken by Mr. Robert Lunn. The photographs of microscopic rock-structures from which the series of petrographical plates was prepared were taken by Dr. Teall. The Bibliography in the Appendix was compiled by Mr. David Tait.

ARCH. GEIKIE,

Late Director-General of the Geological Survey.

Shepherd's Down, Haslemere,
29th June, 1907.

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GEOLOGY

OF THE

NORTH-WEST HIGHLANDS.

CHAPTER I.

INTRODUCTORY.*

In the North-West Highlands of Scotland four great rock-groups are remarkably developed, each characterised by a peculiar type of scenery and illustrating in a vivid manner the intimate relation that exists between geological structure and the evolution of mountain-forms. Each group has impressed its own individuality on the landscape in such a manner as to arrest the attention not merely of the geologist but even of the casual and unscientific traveller. These four groups are in consecutive order from west to east—1st, the Lewisian or Fundamental Gneiss; 2nd, the Torridon Sandstone; 3rd, the Cambrian formation; and 4th, the Eastern Schists. Ever since the time of Macculloch, at the beginning of last century, the stratigraphical position and relative age of these rocks have been a subject of animated discussion and, for a time, of keen controversy. Relying on the apparent order of superposition, the earlier observers naturally inferred from the magnificent sections laid bare along the western fjords and on the grand escarpments and dip-slopes of the mountains that the Eastern Schists follow the Cambrian strata in conformable sequence. But the geological structure which seems at first sight so simple, has proved, on later detailed examination, to be extremely complicated. The apparent succession has been found to be deceptive, and the superposition, which is undeniable, is now ascertained to be due to great terrestrial displacements, which have no parallel elsewhere in Britain.

At the outset it is desirable to indicate briefly the distinctive surface-features and field relations of these rock-groups, so that the reader may form some conception of the history of a region which presents such fascination for the geologist. The several areas covered by the respective formations will be best understood from the geological map which accompanies this Memoir.

i. Along the western seaboard of the counties of Sutherland and Ross, the Lewisian or fundamental gneiss forms an interrupted

* By J. Horne.

belt stretching from Cape Wrath to Loch Torridon, and thence to the islands of Rona and Raasay. Throughout this belt of country bare rounded domes and ridges of rock, with intervening hollows, follow each other in endless succession, forming a singularly sterile tract, where the naked rock is but little concealed under superficial deposits, and where the surface is dotted over with innumerable lakes and tarns. (Plate I.) Over wide areas the elevation of this undulating rocky plateau is comparatively uniform, save near the great escarpments of Torridon Sandstone and Cambrian quartzite, where the Lewisian Gneiss sometimes forms prominent peaks and lofty crags, as on Ben Stack (2364 ft.), near Loch Laxford in Sutherland, and on Ben Lair, near Loch Maree (2817 ft.) in Ross-shire.

The various rocks comprised under the designation of Lewisian Gneiss may be said to form the foundation stones of Scotland. They occupy a well-defined position beneath the Torridon Sandstone and Cambrian strata. Their banded and foliated structure was, by the older investigators, regarded as indicating them to have been originally sedimentary deposits that have been rendered crystalline by various metamorphic processes. The detailed examination of the region, however, leads to the conclusion that these rocks may be arranged in two great divisions—(1) a Fundamental Complex, composed mainly of gneisses that have affinities with plutonic rocks, and to a small extent of crystalline schists and limestones which are probably of sedimentary origin; (2) a great series of igneous rocks intrusive in the Fundamental Complex in the form of dykes and sills.

The rocks that have affinities with plutonic igneous products have a wide petrographical range, and comprise ultrabasic, basic, and more acid materials, such as pyroxenites, hornblendites, together with pyroxenic, hornblendic, and micaceous gneisses. Sometimes they appear in an amorphous form, like ordinary eruptive masses, sometimes with crude banding due to a rough parallel arrangement of the constituents, and yet again, over wide areas, with well-defined foliation. In certain tracts they are thrown into gentle arches and troughs, and in others they are sharply plicated with nearly vertical axes. The altered sediments embrace such familiar types as quartz-schists, mica-schists, graphite schists and limestones, which in hand specimens are indistinguishable from similar rocks in the metamorphic series in the counties of Banff, Perth and Argyll in the Eastern Highlands.

After the gneisses of the Fundamental Complex had acquired their mineral-banding, a subsequent uprise of igneous materials took place along more or less highly inclined fissures. These igneous protrusions, which now appear as dykes and sills, form one of the most striking features of the Lewisian gneiss. (Plate II.) In the undeformed areas they may still be traced through the Fundamental Complex with as much ease as the Tertiary basalt-dykes in the west of Scotland can be followed through the Jurassic strata. Like the gneisses which they traverse, these intrusive masses have a wide petrographical range, including ultrabasic, basic, intermediate and acid types. By the help of these

Plate 1.

Plateau of Lewisian Gneiss, south-east of Lochinver, Sutherlandshire. Suilven and Cùl Mòr in distance.

PLATE II.

Epidiorite Dykes in thrust Lewisian Gneiss. Heights of Kinlochewe, Ross-shire.

intrusions much light has been thrown on the subsequent modifications of the Lewisian Gneiss.

After the eruption of these various dykes and sills, and long before the deposition of the overlying Torridon Sandstone, the whole region of north-west Scotland was subjected to terrestrial stresses which affected both the Fundamental Complex and the intrusive masses which penetrate it. These movements have followed lines or planes of disruption which traverse the gneiss plateau in various directions, sometimes at an oblique angle to the course of some of the intrusions or nearly east and west, and again approximately parallel with the trend of the basic dykes or W.N.W. In the former case, the dykes have been deflected from their normal course, and have undergone such an internal reconstruction as ultimately to pass into hornblende-schists. In like manner, the coarse gneisses with mineral banding have been rapidly folded, a molecular re-arrangement of their constituents has been superinduced, and they are now seen to pass into granulitic gneisses, which, in some instances, are indistinguishable from certain types of altered sediments.

Similar changes are observable when the lines of movement are more or less parallel with the course of the basic dykes, but, in such cases, both the members of the Fundamental Complex and the later intrusions may be plicated on nearly vertical axes or thrown into broad arches and troughs. Here again it can be demonstrated that, by differential movements of the constituents, new foliation planes have been developed alike in the dykes and gneiss. In certain areas the basic dykes appear merely as bands of hornblende-schist in the midst of biotite-gneiss, having thus become an integral part of the complex.

From such evidence, which will be presented in full detail in the sequel, the general principle is deduced, that under the influence of earth-movements which operated in pre-Torridonian time, coarsely-banded gneisses with massive intrusive dykes may be entirely reconstructed and may pass into granular and granulitic gneisses and schists, the planes of foliation being more or less parallel with the axial planes of folding or lines of disruption.

In connection with these reconstructed gneisses and the accompanying lines of movement, bands of mylonised or ground-up rocks (Lapworth, 1885) occasionally occur, which, under the microscope, show the various stages in the breaking down of the original constituents.

All these varied phenomena are undoubtedly of pre-Torridonian age, for the shear-lines and the reconstructed gneisses and dykes can be traced across the plateau of Lewisian gneiss till they disappear under the great escarpment of overlying Torridon Sandstone. This evidence is still further strengthened by the occurrence of fragments of these materials in the basal breccias of that formation.

If the stratigraphical relation of the altered sediments of the Lewisian gneiss to the gneisses that have affinities with plutonic rocks could be definitely ascertained, it would possess much geological interest, in view of the great antiquity of these sediments and the relative ages of the original types of gneiss. There is no clear evidence that these types are intrusive in the former, but, in certain places, the two are so intimately associated as to suggest that the rocks of igneous origin may have been injected into those of sedimentary origin. On the other hand, there is undoubted proof that, north of Loch Maree, the altered sediments rest on a platform of gneiss and are locally overlain by gneiss with basic dykes, the superposition of the gneiss on the sediments being there due to folding and thrusting.

One of the most impressive features in the history of the Lewisian gneiss is the abundant evidence of prolonged denudation between the cessation of the terrestrial movements just described and the deposition of the Torridon Sandstone. During the protracted interval represented by this denudation the gneiss-plateau formed a land-surface which was carved into lofty hills with craggy slopes and deep valleys. This fragment of primeval Europe has been preserved under the pile of coarse Torridonian grits and sandstones which is now undergoing slow removal by the agents of waste. The observer may climb one of these Archæan hills, following the boundary line between the Lewisian rocks and the younger formation, and note, step by step, how the sub-angular fragments of hornblende-schist that fell from the pre-Torridonian crags are intercalated in the grits and sandstones, thus indicating the slow submergence of the old land-surface beneath the waters of Torridonian time. Between Loch Maree and Loch Broom it is possible to determine the orientation of these buried valleys and to prove that some of the hills exceeded 2000 feet in height.

There can be no doubt, therefore, that the unconformability between the Lewisian gneiss and the overlying Torridon Sandstone represents a vast lapse of time. It is analogous to that at the base of the Old Red Sandstone in the Eastern Highlands and at the base of the Trias in England, and differs in a marked degree, as will presently be shown, from the boundary between the Torridonian and Cambrian strata.

ii. The contrast between the scenery of the Lewisian gneiss and that of the overlying Torridon Sandstone is extremely marked. The rounded domes and ridges of gneiss pass underneath a great pile of grits and sandstones, which rises into picturesque mountains over 3000 feet in height. Owing to the gentle inclination of these strata, the successive outcrops form a series of parallel bars or terraces which can be traced by the eye for miles along the eastern margin of the old gneiss plateau. They are intersected by numerous joints and small faults along which erosion proceeds more rapidly, and the escarpments are thus broken up into huge buttresses that in time become isolated from the main area of the formation. (Plates I. and III.)

The Torridon Sandstone has been divided by the Geological Survey into three groups, of which the middle or Applecross division has the greatest development and widest distribution.

Torridonian Precipices: Sgurr na Caorach, Applecross, Ross-shire.

Consisting of coarse sandstones or arkose with scattered pebbles, the members of the Applecross group range from Cape Wrath to Sleat in Skye, preserving throughout their individual characteristics and peculiar bedding. It is remarkable that their enclosed pebbles include pieces of quartzite which show contact-alteration, spherulitic jaspers that have been formed by the silification of liparites, and spherulitic felsites which closely resemble those of Uriconian age in Shropshire. As these fragments have all been derived from formations that are not now visible anywhere in the western part of the counties of Sutherland and Ross, they furnish further evidence of the denudation of the Archæan plateau in pre-Torridonian time.

The members of the lowest (Diabaig) division have not been recognised north of Assynt, and as they are traced southwards to Skye they gradually increase in thickness from 500 feet in the Loch Maree district to about 6000 feet in Sleat. In the sandstones of this group and of the overlying division lines of heavy minerals, such as magnetite, ilmenite, zircon and rutile frequently occur.

The sediments of the upper division (Aultbea), though of local development between Loch Ewe and Loch Broom in the west of Ross-shire, are of considerable interest owing to the occurrence of certain phosphatic nodules in dark micaceous shales. The chemical composition of these nodules would of itself suggest a probable organic origin, and in support of this inference it may be mentioned that Dr. Teall has found them to contain spherical cells with brown-coloured fibres, which appear to be organic structures. (Plate LII.) With this exception, no undoubted organic remains have been found in the Torridon Sandstone.

These Torridonian deposits were grouped with the Cambrian system of Wales, until 1901, when the discovery of the *Olenellus* fauna in the overlying quartzite-limestone series demonstrated that they must be older than even the lowest division of that system and are thus of pre-Cambrian age. The observer who climbs the mountains of Torridonian rock will not wonder that they should once have been relegated to the Old Red Sandstone, when he notes the unaltered character of these sediments, the freshness of their constituents and the absence of kaolinisation in the felspars. Yet, while this is their normal character, it is worthy of note that where they have come under the influence of the great post-Cambrian earth-movements, they have been so altered as to approach the type of crystalline schists.

iii. The third of the rock-formations, formerly grouped by Murchison with the Silurian system, but now proved to contain organic remains of Cambrian age, presents a succession of strata wherein the lowest and most prominent subdivision is a group of quartzites. Though only about 500 feet in thickness, these pale siliceous rocks form a conspicuous feature in the landscape, seeing that they give rise to snow-white escarpments and outliers which cap the mountains of Torridon Sandstone or even of the Lewisian gneiss. (Plate IV.) Sometimes they form long-dip slopes, as on the west side of Loch Eireboll or in the mountains in the Dundonnell Forest south of Loch Broom, where they retain with remarkable freshness the striæ produced during the glaciation of the region. Next in order come two sub-zones together about 70 feet thick, comprising brown dolomitic shales followed by a band of quartzite (*Salterella* grit) which have yielded the *Olenellus* fauna. These are overlain by the dolomite and limestone, which reach their greatest development (1500 feet) in the Durness basin.

One of the prominent structural features in the North-West Highlands, which catches the eye of the geologist, is the boundary line between the white Cambrian quartzite and the dark red or brown underlying Torridon Sandstone. As shown by Professor Nicol and Sir Henry James this line marks not merely the junction of two distinct groups of sedimentary strata, but a great unconformability which can be traced from north to south across the counties of Sutherland and Ross into Inverness-shire. It further implies prolonged marine denudation and differs completely in character from the eroded land-surface at the base of the Torridon Sandstone. The detailed mapping shows that during the interval of time represented by this unconformability, the Torridon Sandstone was gently folded, a vast thickness of strata was then removed and the Lewisian gneiss was exposed over wide areas, before the marine sediments of Cambrian time were laid down. Hence we find in that region numerous instances of that remarkable structure—the double unconformability—so well displayed on the hill slopes south of Loch Assynt, where the edges of the nearly horizontal Torridon Sandstones are transgressed, bed after bed, by the more highly inclined Cambrian quartzites, till the latter rest directly on the Lewisian gneiss. (See Figs. 31 and 36.) By this means also various outliers of Torridon Sandstone were formed, to the east of the present apparent limit of the formation, which were carried westwards by the later post-Cambrian movements. It is further interesting to observe that wherever the surface of the Lewisian gneiss can be examined underneath the basal quartzites, the felspars in the rocks that formed the old sea-floor show a peculiar type of decomposition and the gneisses themselves are epidotised.

An attentive examination of the North-West Highland region proves the accuracy of Professor Nicol's conclusion that the limestone is the highest member of this system. No evidence now remains to show whether or not the Cambrian limestones and dolomites were covered by conformable sediments of younger date, for the record is interrupted at that horizon by a great series of displacements to which allusion will presently be made.

After the deposition of the Cambrian dolomites and limestones, and before the development of the post-Cambrian movements, the members of that formation and of the underlying Torridon Sandstone were pierced by sheets or sills and plutonic masses of various igneous materials. Though traceable from Loch Glencoul to Ullapool, they are specially numerous in the neighbourhood of Inchnadamff, where they form noticeable features in the landscape,

Unconformability of Cambrian Quartzites on Torridon Sandstone. Loch Coire Mhic Fhearchair, Beinn Eighe, Ross-shire.

certain zones in the Cambrian formation,—the basal limestone, the Serpulite Grit and the "Fucoid Beds" have yielded readily to the intense lateral pressure, for they have been piled up in small slices that dip at an oblique angle to the plane along which they have been driven. (Figs. 31 and 28.) But such structures appear only in advance of, or beneath, the great disruption lines or thrusts which are arranged in definite order from west to east. The more westerly of these thrusts detach, bring up and drive westwards portions of the old floor of Lewisian gneiss, together with the Torridon Sandstone and many of the fossiliferous zones of the Cambrian series. The slices of Lewisian gneiss sometimes exceed 1000 feet in thickness, and they present the characteristic types of these rocks as developed in the undisturbed area to the west. In certain localities inversions occur on a stupendous scale, as, for example, to the north and south of Stromeferry, where a portion of the old Archæan floor of gneiss has been turned upside down and there reposes on the inverted basal beds of the Torridon Sandstone which dip at gentle angles to the E.S.E.

The most easterly and perhaps the most powerful of these disruptions, to which the name of "Moine Thrust" has been given, differs from all those to the west in two important points. First, the materials overlying that plane comprise the Eastern Schists—the fourth of the great rock-groups referred to at the beginning of this Chapter—which possess different petrographical characters from the displaced masses to the west. Secondly, in some instances, the strata overlying this plane have been driven so far west—for ten miles at least in the Durness area—that they rest almost directly on the undisturbed Cambrian rocks. Hence arise those deceptive sections where there seems to be a normal sequence from the fossiliferous Cambrian zones into the Eastern Schists.

These displacements were accompanied by differential movement of the component materials of the rocks affected, and resulted in the development of new structures which reach their highest limit of metamorphism along the belt of strata in association with the Moine Thrust. There a prominent zone of crushed or mylonised rocks is usually to be seen. The Lewisian gneiss, Torridon Sandstone, and Cambrian quartzite have been so sheared and rolled out that they now present new divisional planes parallel with that of the Moine Thrust. The Lewisian gneiss shades into flaser-gneiss with lenticular or phacoidal structure, and ultimately passes into a banded rock like a platy schist. The pegmatites show beautiful fluxion-structure, with felspar "eyes" like rhyolites.

No less interesting and important is the evidence furnished by the deformation of the sediments. In the case of the "pipe-rock zone" of the quartzite, the vertical worm-casts have been bent over and flattened till they become parallel with the plane of thrust, and the beds have been much attenuated. In the Torridon grits and sandstones, the quartz-grains have been drawn out into lenticles that wind round the "eyes" of felspar; sericitic mica appears in the divisional planes, and in some instances biotite has been deve-

ii. TORRIDONIAN -	3. Sandstones and dark micaceous shales. 2. Thick series of coarse sandstones and grits with conglomerate bands. 1. Dark and gray shales with calcareous bands, fine-grained sandstones and grits with epidotic grits at the base.

[Strong Unconformability—Highly-eroded land surface.]

i. LEWISIAN - -	Complex of pyroxenic, hornblendic, and micaceous gneisses with certain crystalline schists that represent altered sediments. This complex is pierced by ultrabasic, basic, and acid intrusions in the form of dykes and sills.

Brief allusion may be made in this preliminary statement to the overwhelming evidence of repeated and prolonged denudation in the North-West Highlands. The materials that overlie the Moine Thrust-plane originally stretched far to the west of the present main outcrop of that plane. By the removal of these materials from an area many square miles in extent, we are enabled to study the complicated structures that once lay buried under a covering of the Eastern Schists. Again, by the recession eastwards of the great Cambrian and Torridonian escarpments, the gnarled Lewisian Gneiss, once so deeply buried under these formations, has been once more exposed, and has revealed some of the topography of the oldest land-surface known to exist in Western Europe, while at the same time the successive protrusions, dislocations, and displacements of the remotest Archæan ages have been laid bare to our eyes.

CHAPTER II.*

PREVIOUS LITERATURE RELATING TO THE GEOLOGY OF THE REGION DESCRIBED IN THIS MEMOIR.

Towards the close of the eighteenth century brief references were made to the occurrence of certain rock-groups in the North-West Highlands, which have now become widely known in geological literature. In 1774 Pennant† recorded exposures of limestone and marble in Ross-shire and at Ledbeg in Sutherland; and in 1789 Williams‡ mentioned that granular quartz or primitive sandstone is found in parts of Ross-shire and the mountains of the north of Scotland.

The first important contribution to our knowledge was made by Macculloch§—the great pioneer in West Highland geology—who, between 1814 and 1824, described a remarkable development of red sandstone, quartz-rock and limestone among the gneiss and schists of the North-West Highlands and Islands. He maintained that the red sandstones and conglomerates (Torridon) rest unconformably on the western gneiss, and that, in Sutherland, they are overlain by quartz rocks and limestone, which alternate with and are succeeded by gneiss and schists forming the chief portion of the Highlands of Scotland. He announced the important discovery of worm tubes (named by Salter, *Serpulites Maccullochii*) and *Orthoceratites* in the quartz rock of Loch Eireboll, and he noted "the occurrence of certain cylindrical bodies" in the quartzites of Assynt and the Coigach. The limestone of the Garbh Island was regarded by him as a fragment of the limestone basin of Durness. Allusion was made to the "red vermicular stains" in its grey base and to the singular forms on its weathered surface, which, in his opinion, indicated that such remains entered into the composition of the rock. He stated that, along the eastern shore of Loch Eirebol, the superposition of the quartz-rock to the limestone and of the gneiss to the quartzite can be seen at various points; and further that, in Sleat and Loch Alsh, at Glenelg and Loch Carron, the red sandstones (Torridon) graduate upwards into gneiss and schists.

* By J. Horne.

† "A Tour in Scotland and Voyage to the Hebrides." Vol. ii., pp. 365, 366.

‡ "The Natural History of the Mineral Kingdom." Vol. i., 1st ed., p. 472.

§ "A Description of the Western Islands of Scotland," vol. i., pp. 1-234, 295, *et seq.*; vol. ii., pp, 89, 104, 508, 515; and vol. iii., with plates and maps. "On the Geology of various parts of Scotland," *Trans. Geol. Soc.*, ser. 1, vol. ii., pp. 388, 450. "A Geological Classification of Rocks," London, p. 333. "Supplementary Remarks on Quartz Rocks," *Trans. Geol. Soc.*, ser. 2, vol. i., pp. 53-60.

From this brief outline it will be seen that this astute observer established two points of permanent value, viz., the unconformability between the western gneiss and the overlying red sandstones (Torridon) and the occurrence of the zone of Serpulite Grit (*Salterella* quartzite). By correlating the limestone at Garbh Island with that at Durness, he inferentially suggested the system of east and west faults in that region, and while noting the occurrence of an upper quartzite and the superposition of the eastern gneiss and schists to the quartzite and red sandstones, he recorded certain facts, the correct interpretation of which led to prolonged controversy in future years.

In 1827 Murchison and Sedgwick visited north-west Sutherland, and in 1829 they communicated to the Geological Society a paper on "The Structure and Relations of the Deposits contained between the Primary Rocks and the Oolitic Series in the North of Scotland," in which they correlated the red sandstones (Torridon) between Cape Wrath and Durness with the red sandstones of Tongue, and thus with the Old Red Sandstone of Caithness.*

In his "System of Geology" which appeared in 1831, Macculloch distinguished between the primary sandstone in Ross and Sutherland, where it is associated with quartz-rock and the secondary sandstones with fossils in the west of Scotland.†

In 1841 Hay Cunningham confirmed Macculloch's observations regarding the unconformability between the red sandstones (Torridon) and the underlying gneiss, and the occurrence of an upper gneiss resting on the quartz-rocks and limestones. He further corroborated the discovery of organic remains in the quartz-rock, and stated that "there are gneisses and mica-slates that have been elaborated after these were called into being."‡

In his volume on "The Old Red Sandstone" published in 1841, Hugh Miller correlated the red sandstones in the west of Sutherland and Ross with the red sandstones in the basin of the Moray Firth. He contended that, in Assynt, these strata are succeeded by (1) a lower quartz-rock; (2) massive limestone, and (3) an upper quartz-rock, the last member being exposed in Glas Bheinn and Ben More. He admitted that, in Eireboll, the eastern gneiss does seem to overlie the quartz-rock.§

In 1844 Nicol referred to the development of the red sandstones resting unconformably on the gneiss in the North-West Highlands, and noted that it is succeeded by quartz-rock and limestone which, at certain localities in Loch Eireboll, pass underneath the Eastern gneiss. He suggested that the primary strata of the Highlands are the metamorphic representatives of the Silurian rocks of the South of Scotland.‖

* *Trans. Geol. Soc.*, ser. 2, vol. iii., p. 125.

† "A System of Geology," vol. ii., ch. 29.

‡ "Geognostic Account of the County of Sutherland," *Trans. High. Soc.*, vol. xiii., p. 73, vol. vii., new series, p. 73.

§ "The Old Red Sandstone," 1st ed., ch. ii. (1841). "On the Red Sandstone, Marble, and Quartz Deposits of Assynt," published in 16th ed., p. 325.

‖ "Guide to the Geology of Scotland," p. 210, *et seq.*

A suggestive memoir was published by Mr. Daniel Sharpe in 1852 on the foliation of the rocks of the Northern Highlands, in which he endeavoured to show that foliation is the ultimate stage of cleavage. He distinguished between the gneiss lying east and west of a line drawn from Loch Eireboll to the head of Loch Maree, the foliation and cleavage of the western area and of Lewis striking north-west and south-east, and that of the eastern area north-east and south-west.*

The discovery by Charles Peach in 1854 of fossils in the Durness Limestone aroused keen interest in these rocks and led Sir Roderick Murchison to revisit the North-West Highlands. He invited Professor Nicol to accompany him, and the two observers went over some of the northern sections together in the autumn of 1855. At the British Association meeting of that year he communicated a paper "On the Relations of the Crystalline Rocks of the North Highlands to the Old Red Sandstone of that region, and on the recent discoveries of Fossils in the former by Mr. Charles Peach," which gave the results of observations made during this joint traverse. Murchison contended that all the crystalline rocks of that area (gneiss, schists, clay-slates) were originally stratified deposits that had been crystallised before the beginning of the Old Red Sandstone period. He correlated the quartz-rocks and limestones of Durness with their equivalents at Eireboll, stating that in the latter region they pass under the eastern gneiss and schists. Owing to their imperfect preservation the age of the fossils could not be definitely determined, but Salter provisionally regarded them as belonging to the Devonian genus *Clymenia* or to *Goniatites* and *Euomphalus*. Murchison suggested that they might be of Lower Silurian age, and hence he separated the western gneiss from the eastern schists, which he considered to be younger than the fossiliferous limestones. The red sandstones of Applecross, etc., were still supposed by him to be the equivalents of the Old Red Sandstone of the east coast.†

An important advance was made by Nicol when, towards the close of 1856, he communicated to the Geological Society a paper "On the Red Sandstone and Conglomerate, and the Superposed Quartz-rocks, Limestones and Gneiss of the North-West Coast of Scotland," wherein he described various sections extending from Loch Eireboll to the southern part of Skye, examined partly in 1855 in company with Murchison, and partly in 1856 by himself.‡ One of the prominent features of this paper is the detailed evidence in support of an unconformability between the red sandstones (Torridon) and the overlying quartzites which he had detected and traced for upwards of 100 miles. The following order of succession is given :—

1. The red sandstone is the lower formation resting on gneiss and forming a narrow band along the western shore, never reaching

* "On the Arrangement of the Foliation and Cleavage of the Rocks of the North of Scotland," *Phil. Trans.*, vol. cxlii., p. 445.

† *Rep. Brit. Assoc.* for 1855, p. 85.

‡ *Quart. Jour. Geol. Soc.*, vol. xiii., p. 17, published in 1857.

the watershed of the country and not exceeding twenty miles in breadth.

2. The quartzite is a distinct and newer formation reposing unconformably on the red sandstone on the west, but on the east spreading out beyond it over the gneiss. Its present breadth, including outlying portions, does not exceed ten miles, and is generally much less. The limestone forms the upper portion of this band.

3. At many points along the eastern margin the quartzite and limestone have been ascertained to dip under gneiss inclined in the same direction towards the south-east.

Nicol suggested that the quartzite occurring east of the limestone in Assynt is probably only the lower quartzite rising from underneath that zone or brought up by a fault. Allusion is made to the rounded bodies of organic origin in the quartzite (pipe-rock) to the plant-like impressions in the Fucoid beds, to the conical bodies (*Serpulites*) found by Macculloch, and to the fossils obtained by Mr. C. W. Peach from the limestone. He was convinced that the age of the beds could be satisfactorily determined only by the discovery of better preserved fossils, but he provisionally regarded the red sandstones (Torridon) as Devonian and the quartzites and limestones as Lower Carboniferous. Should the latter prove to be of Silurian age, then the Torridon Sandstone would necessarily belong to a different period from that of the Old Red Sandstone with which it had been identified. In several horizontal sections illustrating this paper, the quartzites and limestones are represented as passing below the eastern gneiss, but Nicol expressed a doubt whether the latter might be a newer metamorphic group or a portion of the lower gneiss forced up by some great convulsion.

The marked unconformability between the red sandstones and quartzites detected by Professor Nicol was observed independently by Sir Henry James and described by him in a letter to Sir Roderick Murchison, dated 26th July, 1856.*

The discovery by Mr. Peach of additional fossils from the Durness limestone, which were considered by Salter to have strong affinities with certain Lower Silurian forms of North America, ranging from the Calciferous Sand-rock to the Trenton Limestone, gave a new impetus to Murchison in his investigation of the structure of the North-West Highlands. In 1857 he made a communication to the Geological Section of the British Association at Leeds,† where he announced that, in view of the unconformability between the red sandstones and the quartzites and the definite nature of the palæontological evidence as interpreted by Salter, he regarded these red sandstones as the equivalents of the Cambrian rocks of Wales. A note by Salter on the fossils from the Durness Limestone is appended to this paper, in which he states that "the character of the fossils is so very similar to that of the lower limestones of America, often contained in a single calcareous band, that

* "Life of Sir R. I. Murchison," by A. Geikie (1875), vol. ii., p. 212.
† *Rep. Brit. Assoc.* for 1857, pp. 82-84.

one is tempted to conclude that the succession in North-West Scotland, where a thick limestone reposes on a quartzite full of fucoidal markings, can be nothing else but the equivalent of the Calcareous Series of Canada, with its underlying Potsdam Sandstone."

In 1858 Murchison and Nicol contributed to the Geological Section of the British Association at Leeds brief statements of their views as to the relations of the rocks in the North-West Highlands. Nicol expressed regret that in one point he was compelled to differ from his friend, that he could not regard the entire gneiss forming the central regions of Ross and Sutherland as of younger date than the red sandstone and quartzite of the West Coast. He described a section from Gairloch to the Moray Firth, and showed that both the red sandstone and quartzite resting on the western gneiss were cut off by igneous rocks from the supposed overlying strata on the east. Similar igneous rocks, occupying the same relative position, had been traced by him at intervals for 100 miles, from Loch Eireboll to Skye, and he therefore concluded that the overlap of the eastern gneiss on quartzite might be caused by a slip or convolution of the strata.*

With unflagging energy, Murchison prepared an elaborate memoir in two parts "On the Succession of the Older Rocks in the Northernmost Counties of Scotland, with some Observations on the Orkney and Shetland Islands," which he communicated to the Geological Society in 1858.† He indicated the characters of the western gneiss as exposed in the low maritime headlands in the west of Sutherland and Ross, where the rocks are variously inclined at high angles and highly contorted, are usually hornblendic, and penetrated by granitic veins. He remarked that it will be for future geologists to observe the extent to which this old rock may reappear in the central or eastern portions of the northern counties of Scotland, for, although he had failed to detect it in the region east of a line extending from Eireboll to Loch Assynt, it might well occur in parts of the interior which he had not explored.

The great succession of Silurian strata resting unconformably on the Cambrian sandstones and the Fundamental gneiss were grouped by him in the following ascending order:—(1) Quartz-rock, (2) limestone, (3) upper quartz-rock, (4) micaceous and chloritic schists passing into a kind of gneiss, with repetitions of quartzose and micaceous flaggy rocks. A description by Salter of the organic remains from the Durness Limestone was given in the same paper, together with figures of some of the fossils, wherein that astute palæontologist made the following striking statement:—"That this truly North American assemblage should be found in the extreme north of Scotland, on the same parallel as the Canadian—that species of *Maclurea* and *Raphistoma*, resembling those of the St. Lawrence basin, and *Orthocerata* bearing large siphuncles like those of North America, Scandinavia, and Russia, should occur in Scotland

* *Rep. Brit. Assoc.* for 1858. Trans. of Secs., p. 96.
† *Quart. Journ. Geol. Soc.*, vol. xv., p. 353.

and yet be scarcely known further south, is at least suggestive of a geographical distribution—perhaps even of climatical conditions—not very unlike that of more modern times."

The marked change in the petrographical characters of the eastern or younger gneiss was again enforced by Murchison. With reference to the outlying mass of the eastern schists at Bishop's Castle,* north of the Durness Limestone basin, he noticed the occurrence there of thin-bedded grey micaceous flagstone (siliceous Moine-schist) that occasionally weathers white, like the promontory of the Whiten Head, east of Loch Eireboll, and remarked that the observer cannot fail to recognise the distinction between the hornblendic and micaceous gneiss to the west, and this outlying crystalline flagstone, which, though it contains felspar, quartz, and mica, is not hornblendic, and is void of granite veins. He recorded the development of this same type of quartzose flagstone and dark grey micaceous schists east of Loch Eireboll and Assynt, which on Ben Hope, east of the former sea-loch, are associated with green and grey micaceous schists with garnets that present the external aspect of the Italian "Cipollino." He had no doubt that the Silurian quartzites and limestones are overlain by the younger micaceous flagstones of Inverhope and the Moine east of Loch Eireboll, both having a common dip towards the E.S.E, and that they constitute one great series, the age of which is determined both by the order of superposition and by the fossils contained in one of its lower members.

In the same memoir Murchison next proceeds to consider Nicol's conclusion that intrusions of igneous rock appear at intervals between the quartzite and limestone and the younger gneiss, which the latter geologist believed to be connected with a general dislocation along the strike. He referred to the Canisp porphyry that pierces the lowest part of the Cambrian sandstone on that mountain, to the hypersthenic rocks that penetrate the limestones of Durness and the quartz-rocks and limestones of Assynt, to the syenite and felspar rocks that reappear above the Silurian limestones at Ledmore and on the banks of Loch Borrolan (Assynt), and to the granite mass of Ben Laoghal rising through the younger gneiss in Sutherland. He maintained that these eruptive masses do not derange the general succession, though they occasion partial folds of the beds near the points of local intrusion.

A geological sketch map of the north of Scotland is appended to this paper, in which the western or Fundamental gneiss is correlated with the Laurentian gneiss of Canada, and the eastern schists, together with the quartzites and limestones, are coloured as of Lower Silurian age.

This elaborate memoir was followed in 1860 by a further contribution from Murchison on "Supplemental Observations on the order of the ancient Stratified Rocks of the North of Scotland and their associated eruptive rocks,"† which embodied the results of a traverse with Sir A. C. Ramsay in the previous year. Again he

* This locality is termed Seanachaisteal on the One-Inch Map 114.

† *Quart. Journ. Geol. Soc.*, vol. xvi., p. 215.

points out the divergence in strike between the Laurentian gneiss and the eastern schists, that of the former being N.N.W. and S.S.E., and that of the latter, approximately, N.N.E. and S.S.W. He advances fresh evidence in support of his contention that the Silurian limestones are intercalated between a lower and an upper quartzite, and that at certain localities there is an upper limestone between the upper quartzite and the eastern schists. On the authority of Professor Harkness, he gives a section showing the upper limestone at Cnoc an Droighin (Inchnadamff), and another showing the upper quartzite and limestone pierced by intrusive rocks on the west face of Ben Arnaboll* (Loch Eireboll). He notes the occurrence of intrusive igneous rocks at various localities near the junction of the quartzite and limestone with the upper gneiss, and contends that they do not affect the order of succession.

In December, 1860, Professor Nicol laid a full and what might be termed a final statement of his views before the Geological Society in a paper, "On the Structure of the North-Western Highlands and the Relations of the Gneiss, Red Sandstone, and Quartzite of Sutherland and Ross-shire." This remarkable contribution embodied the results of his researches extending over several years in the North-West Highlands, and in view of the rare power which it reveals in dealing with complicated tectonics it ought to be studied by all those who are interested in this controversy.†

In regard to the relation of the quartzite to the eastern gneiss, discussed in his previous communication to the society in 1856, Nicol stated that "though some of the sections appeared to confirm Macculloch's view that there are in Sutherland two formations of gneiss—an older below the quartzite and a newer superior to it—still the presence of intrusive rocks and other marks of disturbance in the sections he had examined rendered this conclusion less certain and satisfactory than might be wished." In order to determine this question he had subsequently visited this region four times and examined all the principal sections and almost the entire tract from the North Coast of Scotland to Skye in the south, and from Caithness in the east to the island of Lewis in the west.

The object of this paper is to prove (1) that the limestone is the highest member of the older formations in this region, (2) that no conformable upward succession from the fossiliferous limestone to the overlying schists is to be found, "but that the line of junction, where this conformable succession is said to occur, is clearly a line of fault, everywhere indicated by proofs of fracture, contortion of the strata and powerful igneous action." By means of horizontal sections illustrating the structure of the Eireboll and Assynt regions he shows that the so-called upper quartzite and upper limestone of Murchison's sections are merely repetitions of the lower quartzite

* Ben Arnaboll is named Beinn Poll Ath-roinn on Sheet 114 of the One-inch map.

† *Quart. Journ. Geol. Soc.*, vol. xvii., p. 85.

and limestone due to faults or folds. He adopted the following order of succession, which is given below in descending order:—

4. Limestone.
3. Quartzite (Serpulite Grit).
2. Fucoid Beds.
1. Quartzite including the pipe-rock with annelid tubes.
   Unconformity.
   Red Sandstone (Torridon).
   Unconformity.
   Gneiss and Crystalline Schists.

In the Durness area, Nicol correlated the white mica-slates of Farrid (Fair aird on Sheet 114) Head and Old Castle Point (Seanachaisteal) with similar rocks east of the quartzite at Eireboll and at Melness (Tongue). The brecciated character of the limestone in Sango Bay is supposed to be due to a mass of hornblende-rock or serpentine that rises up in that bay, bringing with it portions of altered quartzite and mica-slate. These igneous and metamorphic rocks extending from Sango Bay south to Loch Cealladail have been evidently forced up through the limestone. The quartzite resting on the limestone in Sango Bay has been broken up into an incoherent breccia by a fault and crush; indeed, the basin is traversed by faults trending N.N.E. and S.S.W., and the strata have been tilted up on the west.

Eastwards in the Eireboll region, Nicol showed that between Camas-an-duin and Eireboll House the limestones form a synclinal fold, and that the underlying Fucoid Beds and pipe-rock appear in regular descending order in the hill-slope to the east. He contended that though the Fucoid Beds and quartzites appear to rest on the limestone with an easterly dip this structure is due to an upheaval and inversion of the strata. In the horizontal section of Camas-an-duin (*ibid.* Vol. XVII., p. 88.) the igneous rock (granulite) is represented as appearing on the ridge of high ground to the east, bounded on the west by quartzite, capped in part by quartzite and succeeded eastwards by mica slate. Nicol argued that as fragments of mica-slate are found in this mass of granulite, they prove that the mica-slate is the lower and older rock, and therefore cannot normally overlie the quartzite. Similar eruptive rocks occur on Ben Arnaboll, on the hills north-east of Hope Ferry, at Whitten Head (Cean Geal Mor), and Creag na Faoilinn. The granulite on Ben Arnaboll has clearly broken through the strata, resting in one place on the Fucoid Beds, in another on the quartzite, and further east towards Loch Hope is overlain by quartzose beds.

Again in his horizontal section of Assynt (*ibid.* Vol. XVII., p. 96) Nicol arranged the series of formations in a great syncline, its centre being occupied by the broad mass of limestone at Inchnadamff, while on the eastern limb the quartzite rises from underneath the limestone on the mountains of Ben More and Braebag. The eastern limit of the section shows what he believed to be the structure of Ben More as exposed in the wild corries round Dhu Loch More. Granitic gneiss and mica-slate, with intrusive igneous rocks, form the nucleus of that mountain, throwing off the quartzite all around as from a great centre of elevation. He there noted also red sandstone resting on gneiss or mica-slate (as shown in his section), regarding which he says (*ibid.*, p. 99) that "there can be no doubt that this is the true western red sandstone (Cambrian of Murchison) brought up in the centre of the so-called upper quartz-rock, and that the synclinal is thus complete in all the formations from the upper limestone to the lowest gneiss." He further stated that "the only obscurity in the sections arises from the synclinal fold in the limestone being conjoined with a great fault in the quartzite, which is thus brought up in enormous crushed masses, so broken that the lines of stratification can hardly be detected; this is especially seen near the foot of Coniveal" (Coinne-mheall) (*ibid.*, p. 97).

Regarding the Loch Ailsh section, Nicol maintained that the upper quartz rock (Murchison) is the continuation of the quartzite of Braebag and Canisp, and that the upper limestone is merely the repetition, in a denuded form on the eastern side of the anticline, of the limestone of Stronechrubie and Assynt.

Various sections in Ross-shire are described by Nicol in support of his views of the relations of the rocks. He refers particularly to one across the mountains east of Loch Torridon (*ibid.*, Fig. 13, p. 104), where five isolated patches of quartzite rest on the red sandstone (Torridon) in one continuous ridge, and maintains that, in this instance, "the quartzite is mere fragments of the upper formation brought down repeatedly by faults, and in some cases even forced in below the inferior red sandstone by enormous lateral pressure."

From the evidence adduced Nicol drew the following conclusions:—

1. The mode of distribution of the rocks is altogether inconsistent with the hypothesis that the eastern gneiss conformably overlies the red sandstone or quartzite.

2. The diversity of strata brought into contact with the eastern gneiss proves that the line of junction is along a fault and not one of conformable upward succession.

3. That there is here a line of fault and not of conformable overlap is proved by the nature of the formations. Though along the line of fault, and especially where the disturbance has been most violent, the quartzite is often much hardened and semi-fused, still its fragmentary and granular character is quite recognisable. On the other hand, the eastern gneiss and mica-slate said to rest on it are no less distinctly crystalline. He therefore inferred that the sections in the North West Highlands are but the counterpart of those in the Alps, where crystalline rocks are seen resting on unaltered strata, due to the enormous inversion and overthrow, and that a comparatively small amount of inversion and extrusion of older crystalline masses will suffice to explain any of the Scottish sections.

Regarding the strike of the crystalline rocks, Nicol admitted that, in the western region, the general trend is north-west and in the central areas north-east, but this distinction is not universal. He suggested that the gneiss of Scotland may belong to distinct geological periods. With reference to the divergence in mineralogical character between the western and eastern gneiss, he conceded that hornblendic varieties of gneiss are very characteristic of this formation in the west of Sutherland, but the more usual kinds also occur, while in the eastern districts he contended that rocks quite as hornblendic and as thoroughly granitic in character are to be found. In his opinion, the peculiar character of the rock has no relation to its age or locality, but to its proximity to the great foci of igneous action. Near the granitic and syenitic eruptions the gneiss appears in the more coarsely crystalline and hornblendic forms.

In the summer of 1860 Murchison revisited the Highlands once again, accompanied by Sir A. Geikie, with the view of tracing the development of the Sutherlandshire series south-westwards through Ross-shire to Skye, and of discovering whether the order observable in Sutherland extended across the mountainous tracts to the south of the Caledonian Canal. For this purpose the authors examined certain sections in the islands of Lewis, Skye, Islay and Jura, likewise in West Ross-shire and south-eastwards to the Highland border. The results of their observations were communicated to the Geological Society in an elaborate memoir in Feb. 1881.*

In the description of the Laurentian gneiss of Lewis, Harris, West Ross-shire, and other localities, Murchison stated that the prevalent strike of the gneiss in those regions is north-west and south-east, and that lithologically it resembled the western gneiss of Sutherland. Once more he emphasised the contrast between the micaceous and hornblendic gneiss underlying the Cambrian Sandstone (Torridon) and the flaggy, quartzose and micaceous strata overlying the limestones and quartzites with a north-east and south-west strike. He declared that "no geologist can confound the Laurentian or Fundamental Gneiss with the so-called gneiss of the superior crystalline schists, which instead of being a massive hornblendic and granitoid rock like the first formed is, on the whole, a flag-like micaceous and quartzose deposit of very different characters." (*Ibid.*, p. 175.)

The distinctive feature of this paper is the description of the relations of the rocks in the tract extending from the southern limits of the county of Sutherland across Ross-shire into Skye. One section in particular—Creag a' Knockan—deserves special notice, as it seemed to furnish evidence of an ascending sequence from the undisturbed Silurian strata (quartzite, Fucoid Beds, limestone) to the overlying quartzose schists without the intercalation of any igneous material (*ibid.*, Vol. XVII., Fig. 2, p. 180),

* "On the Altered Rocks of the Western Islands of Scotland and the North-Western and Central Highlands," *Quart. Journ. Geol. Soc.*, vol. xvii., p. 171.

and without the synclinal folding of the beds as shown in Nicol's section of the same cliff (*ibid.*, Vol. XVII., Fig. 10, p. 101). Similar evidence is adduced along the line southwards towards Ullapool. Beyond Loch Broom the authors refer to an interesting section at Loch-an-Nid (*ibid.*, Fig. 7, p. 188), where on the east slope of Sgùrr Ban there are two small dark peaks—outliers of a green serpentinous and actinolitic gneissose rock—which are distinctly superposed on the inclined bedding-planes of quartz-rock. Still further north, the development of the rock in Glen Bruachaig, near Kinlochewe is referred to, which seems to invade the quartz-rock, the limestone, and the upper flaggy series, but though it occupies a considerable area the authors contend that it does not interfere with the ascending sequence. The remarkable section on Beinn Liath Mhor, also figured by Nicol (*ibid.*, Vol. XVII., Fig. 13, p. 104), is described (*ibid.*, Fig. 13, p. 196), which shows several intercalations of quartzites in the Cambrian sandstones, their relations being accounted for partly by faults. But in this case and in others where faults or igneous rocks may intervene, the authors maintain that they do not affect the conformable sequence.

From the Silurian base line south-eastwards by the Great Glen and the Black Mount to Loch Tay and Dunkeld, the general relations of the strata are traced with the result that the younger gneiss is believed to have a wide distribution in the central and eastern Highlands, while the quartzites and limestones are supposed to emerge south-east of the Great Glen in the counties of Aberdeen, Perth, and Argyll.

In the course of these traverses the authors made certain observations on the relation between stratification and foliation in the crystalline schists, which were published as a sequel to the memoir just referred to.* They adhered to the views of Hutton that the crystalline rocks of the Highlands were originally sedimentary deposits, their crystalline structure being developed after their deposition. Dissenting from the views of Mr. Sharpe, they maintained that the foliation of the schists concides with the original bedding planes, being "nothing more than such an alteration of the original deposits as caused the siliceous, felspathic and micaceous ingredients to form separate layers." (*ibid.*, p. 240.)

At this stage in the review of this controversy it is desirable to state clearly that the detailed mapping of the region between the north coast of Sutherland and Skye has completely confirmed Nicol's conclusions—(1) that the limestone is the highest member of the Durness series; (2) that the so-called Upper Quartzite and Upper Limestone of Murchison's sections are merely the repetition of the lower quartzite and limestone due to folds or faults; (3) that there is no conformable sequence from the quartzites and limestones into the overlying schists; (4) that the line of junction is a line of fault indicated by proofs of fracture and contortion of the strata. In the course of his investigations Nicol's views

* "On the Coincidence between Stratification and Foliation in the Crystalline Rocks of the Scottish Highlands," *ibid.*, vol. xvii., p. 232.

underwent a process of evolution, and in the form in which he finally presented them he did not grasp certain points which have been established by later observers. We now know that he was in error when he regarded portions of the Archæan gneiss, occurring in the displaced masses, as igneous rocks intruded during the earth-movements, and when he thought the eastern gneisses and schists were merely the old western gneiss brought up to the surface again by great faults. He failed to realise the evidence bearing on dynamic metamorphism resulting from the gigantic disturbances to which the region had been subjected. But notwithstanding these points, he displayed the qualities of a great stratigraphist in grappling with the tectonics of one of the most complicated districts in Europe.

On the other hand, the detailed mapping has proved the accuracy of Murchison's contention that the quartzose and micaceous flagstones and garnetiferous mica-schists which overlie the quartzites and limestones with a general agreement in dip and strike, are so strikingly different lithologically from the western gneisses that they cannot be merely that ancient rock brought to light by faults. The petrographical study of these rocks has shown that, while the larger part of the old gneiss now exposed in the west of Sutherland and Ross has affinities with plutonic igneous products, the eastern gneisses and schists represent in the main a succession of altered sediments (the Moine Series of the Geological Survey, Caledonian Series of Dr. Callaway) save in certain areas where gneisses of Lewisian types come to the surface. Special reference will be made in Part V. to these altered sediments, the age of which has not yet been satisfactorily determined.

Before considering the work of later observers, allusion must be made to the fact that both Murchison and Nicol clearly recognised the intrusive character of the great series of post-Cambrian igneous rocks which are so largely developed in Assynt. In 1859 Murchison noted the band of syenitic greenstone* intercalated in the limestone about a mile west from Inchnadamff and the contact alteration produced by it in the overlying rock which has been converted in parts into a crystalline marble; he also recorded the great development of syenite between Ledbeg and the Oykel Bridge.†

In 1860 Nicol announced that, in the course of the previous year, he had observed that the Canisp porphyry not only breaks through the quartzite overlying the Torridon Sandstone, but forms a mass more than a mile in diameter in the quartzite within a few hundred yards of the Inchnadamff Hotel. From these facts he inferred that the igneous intrusions must have been later than either the red sandstone (Torridon) or quartzite.‡

The order of succession advocated by Murchison and supported by Ramsay, Harkness, A. Geikie, and others, seemed to furnish a

* *Quart. Jour. Geol. Soc.*, vol. xvi., p. 221.
† *Ibid.*, p. 232.
‡ *Ibid.*, vol. xvii., p. 99.

simple solution of the geological phenomena of the North-West Highlands, and hence met with general acceptance.

In 1878 the controversy was re-opened by Dr. Hicks in a paper "On the Metamorphic and Overlying Rocks in the neighbourhood of Loch Maree."* While agreeing with Murchison that there is a perfect passage from the quartzites, Fucoid Beds, and limestones into the overlying flaggy strata of Glen Logan (Glen Bruachaig on one-inch Sheet 92) and Glen Docherty (Eastern schists) resembling the Lower Silurian flags of Wales, he maintained that these flaggy rocks rest unconformably on the pre-Cambrian Archæan rocks of Ben Fyn to the east (Fionn Bheinn, Sheet 92). He also regarded the mass of syenite and granitoid rock in Glen Logan ("Logan Rock" of Heddle) as intrusive and of later date than the Silurian strata. Subsequently Dr. Hicks disputed that the eastern schists rest conformably on the quartzites and limestones, and he abandoned the view that the igneous rock in Glen Cruchalie (Glen Bruachaig on Sheet 92) is intrusive in the latter. He arranged the pre-Cambrian rocks in three groups—(*a*) lower, consisting of massive gneisses (Loch Maree); (*b*) middle, comprising more banded gneisses (Loch Shiel); (*c*) upper, composed of crystalline schists (Ben Fyn); and contended that between Glen Shiel and the eastern border of the Highlands there are representatives of various Archæan rocks with patches of Silurian strata resting on them unconformably.

The mammillated contour so characteristic of the plateau of Lewisian gneiss was attributed by Sir A. Geikie in 1880† to the action of land-ice, and he compared the overlying breccia of Torridon Sandstone age that fills up the hollows and buries the rounded domes of rock near Gairloch to moraine stuff.

In 1880 the first important advance towards the solution of the problem of the succession in the North-West Highlands since the publication of Nicol's researches was made by Professor Bonney, who described the so-called "intrusive syenite" of Glen Logan (Glen Bruachaig on sheet 92), pointing out the occurrence of foliation in the rock, the north-west strike, from which he inferred that all the so-called syenite, save some dykes, is simply a rather granitoid variety of the Hebridean gneiss. He showed that its junction with the limestone, Fucoid Beds, and quartzites is a faulted one, and indicated the direction of the fault. He called attention to a marked fragmental structure in a green schist occurring in the mass, which he attributed to crushing *in situ*.‡ He disputed the statement of Dr. Hicks about the unaltered character of the newer series in Glen Logan and pointed out that

* *Quart. Jour. Geol. Soc.*, vol. xxxiv., p. 811. "On the pre-Cambrian Rocks of West and Central Ross-shire," with Petrological Notes by T. Davies, *Geol. Mag.*, decade 2, vol. vii., pp. 103, 155, 222, 266. "On some Recent Researches among the pre-Cambrian Rocks of the British Isles," *Proc. Geol. Assoc.*, vol. vii., p. 59. "On the Metamorphic and Overlying Rocks in parts of Ross- and Inverness-shires," *Quart. Jour. Geol. Soc.*, vol. xxxix., p. 141.

† *Nature*, vol. xxii., p. 400.

‡ Petrological Notes on the Vicinity of the Upper Part of Loch Maree," *Quart. Jour. Geol. Soc.*, vol. xxxiv., p. 93.

they are rightly classed with the metamorphic rocks as they consist of dark green schists, dull coloured mica-schists and micaceous quartzites.

In 1881 Professor Heddle published a Geological Map of Sutherland, in which he separated the Hebridean or western gneiss from the upper or eastern gneiss, and regarded the limestone of Durness as Silurian and the dolomite between Loch Eireboll and Stromeferry as Archæan. The important feature of this map lay in the detailed representation of the various isolated areas of "Logan Rock," which are now known to be thrust masses of Lewisian gneiss, displaced by post-Cambrian movements, between Loch More and the southern limits of the county. In a series of papers by the same author which appeared in the *Mineralogical Magazine*,* based on observations made by him during extensive traverses throughout the county, the evidence for this classification was given. He maintained that the eastern schists and gneiss rest conformably on the quartzo-calcareous series which extends from Loch Eireboll to Loch Kishorn, the whole being regarded as Archæan, because the calcareous rocks at Durness had not been proved to be the same as those at Loch Eireboll. He contended that chemical analysis showed the calcareous strata at Durness to be limestones and those at Loch Eireboll to be dolomites. He regarded the limestones and quartzites of the Durness basin as a fragment of Silurian strata let down by faults intersecting at three points and having no relation with the quartzo-calcareous series of Eireboll. He applied the term "Logan Rock" (from Glen Logan near Kinlochewe—Glen Bruachaig on Sheet 92) to the thrust masses of Lewisian gneiss, and indicated certain petrological differences between this rock and the western gneiss. Following the classification of Cunningham, he grouped the "Logan Rock" with the Upper Gneiss and defined it as "a grit which presents varying degrees of metamorphism up to a perfect gneissic structure." He further gave a large list of minerals from the crystalline schists and gneisses throughout the county, and described various types of the post-Cambrian intrusive rocks that are so abundant in Assynt.

In 1880 Dr. Callaway visited Durness and Inchnadamff, the results of his observations being communicated to the Geological Society in the following year.† Regarding the Durness sections, he indicated the existence of an east and west fault separating the gneiss and schists of Farrid Head (Fair-aird on Sheet 114) and Bishop's Castle on the north from the Durine limestone on the south, and claimed that hence there can be no conformable sequence between the two at that point. He noted the occurrence of chloritic and hornblendic gneiss underlain by dark mica-schist in Sango Bay, which he believed to be faulted against the limestone on both sides. The author correlated the Sango Bay gneiss with that which

* "On the Geognosy and Mineralogy of Scotland," *Mineralog. Mag.*, vol. iv., pp. 135, 197; vol. v., pp. 71, 133, 216, 271.

† *Quart. Jour. Geol. Soc.*, vol. xxxvii., p. 239.

underlies the flaggy schists on Farrid Head and east of Loch Eireboll, and separated it from the Lewisian or Hebridean gneiss. According to Murchison's view the Sango Bay gneiss and schist overlie the limestone, but Dr. Callaway considered that it is "more reasonable to infer that the limestone was deposited on the contorted gneiss, and that the latter was subsequently thrust up through the former between two parallel faults" (*ibid.*, p. 242).

In 1881 Professor Hull stated in reply to objections advanced by Dr. Callaway that he concurred with Murchison's interpretation of the succession north of the Caledonian Canal. From an examination of the sections near Ullapool, at Inchnadamff, in the Forest of Arkle, and the hills bordering Loch Stack, he considered the geological sequence to be remarkably clear, and thus proving a regular passage from the quartzites and limestones to the eastern schists.*

Similar views to those of Professor Bonney regarding the "Logan Rock" were advanced by Mr. Hudlestone in 1882, who described it as the local representative in the Ben More Assynt range of the Fundamental Gneiss, and "as the frame work or core round which the newer rocks are folded." He disputed the existence of the "upper quartzite," but considered that the section at Creag-a'-Knockan shows a regular ascending series from the Silurian rocks to the upper gneiss.†

The investigations of Dr. Callaway relating to the districts of Loch Broom, Assynt, and Loch Eireboll still further weakened the belief in Murchison's order of succession. A detailed account of his researches was communicated to the Geological Society in 1883, and published in that year.‡ His view of the relation between the Durness Limestone and the eastern gneiss differed to some extent from all those previously advanced, though it approximated most nearly to that of Nicol. He maintained with that author that the junction of the limestone with the eastern gneiss is a line of faulting and inversion; at the same time he recognised the lithological distinctions between the western and eastern gneisses, and grouped them in two great formations of pre-Cambrian age—(*a*) the Hebridean, (*b*) the Caledonian—the latter resting unconformably on the former. He maintained that Nicol's "igneous rock" (granulite), which overlies the limestone in certain localities, is usually a true gneiss, and that both the older and younger gneissic systems have been brought up over the limestone by overfolding and faulting without materially altering their original structures.

While admitting the chemical distinction between the limestone of Durness and the dolomite of Eireboll (*ibid.*, p. 363), referred to by Dr. Thomas Anderson and Professor Heddle, Dr. Callaway regarded the quartzo-calcareous rocks of the two areas as of the

* "The Geological Age of the North Highlands of Scotland," *Nature*, vol. xxiii., p. 289.

† "First Impressions of Assynt," *Geol. Mag.*, decade 2, vol. ix., p. 390.

‡ "The Age of the Newer Gneissic Rocks of the Northern Highlands," *Quart. Jour. Geol. Soc.*, vol. xxxix., p. 355.

same age. Under the term Assynt Series he included the following sub-divisions—C_1, Torridon Sandstone and Ben More Grit; C_2, the Quartzite, comprising a lower seamy subgroup and an upper Annelidian or pipe-rock zone; C_3, Fucoid Beds; C_4, Salterella Grit and Quartzite; C_5, Dolomite. He described in detail various sections in the districts of Ullapool, Assynt, and Loch Eireboll, and gave the following summary of his results:—

1. The Assynt Series has been doubled back on itself in a compressed synclinal fold along Loch Eireboll, so that the quartzite is brought up on the dolomite. In Assynt, also, the quartzo-dolomitic group has been folded back, though less conspicuously. On Loch Broom the dolomite does not come into contact with the Eastern Gneiss, but is separated from it by older faulted rocks.

2. The Assynt Series and the Eastern Gneiss, in the three areas described, display a discordant strike and dip. On Loch Broom the dip of the former is north-easterly, that of the latter south-easterly. In Assynt, where the rocks are in contact, as at Glen Coul, the dip of the gneiss is north-easterly, that of the quartzite south-easterly. On Loch Eireboll there is a double discordance, both the gneiss and quartzite, taking them from north to south, coming respectively into contact with higher and higher beds of the other group.

3. The "Igneous Rock" of some authors, "Logan Rock" of Dr. Heddle. is usually the Hebridean gneiss. On Loch Broom it is brought into contact with almost every member of the Assynt Series in turn, and slightly overlies them. In Assynt this gneiss, sometimes accompanied by the Torridon Sandstone, is thrown over on to the Assynt Series, the overthrow increasing in breadth northwards, so that on Loch Glen Coul it is more than a mile wide. The "intrusive granulite" of Nicol is the Arnaboll gneiss overlying the quartzite and associated rock.

4. The patches of quartzite resting on the "granulite" east of Loch Eireboll are really outliers of the Assynt Series resting unconformably on the Arnaboll gneiss. The absence of granite veins in the Assynt Series supports this conclusion.

5. The "Upper Quartzite" of Murchison's sequence is, in Assynt, the quartzite below the dolomite repeated east of the fault that brings up the Hebridean gneiss. On Loch Eireboll it is the same quartzite repeated on the eastern side of the great synclinal fold.

6. The "Upper Limestone" is, on Loch Ailsh, marble and crystalline dolomite intercalated in the Caledonian series. Near the Stack of Glen Coul it is the Assynt dolomite repeated east of the fault that brings up the Hebridean gneiss. Above Eireboll House it is a faulted fragment of the dolomite appearing east of the inverted quartzite.

7. The Eastern Gneiss, though actually overlying the Assynt Series in some localities, has been brought into this abnormal position by earth-movements subsequent to the deposition of the latter, and is of greater antiquity.

8. **The Eastern Gneiss is widely separated in age from the Hebridean rocks.**

In the Appendix to Dr. Callaway's paper (*ibid.*, Vol. XXXIX, p. 416.), Professor Bonney describes the microscopic characters of some of the thrust Hebridean gneisses in Assynt and at Ullapool which show indications of crushing and recementation. In some instances these features have so obscured the original structures that it is difficult to determine the true characters of the rocks.

Subsequently Dr. Callaway referred to certain localities where the members of the Assynt Series become more highly altered towards the junction with the Archæan Gneiss, when the latter by folding or thrust has been made to overlie the former. He maintained that there is no material alteration in that series underlying the Hebridean gneiss in Glen Coul, because there is no evidence of extraordinary pressure; but near the base of the Stack of Glen Coul, at the junction with the eastern gneiss (Caledonian), the quartzite looses all traces of clastic structure and passes into quartz-schist. He accounts for this progressive alteration by enormous pressure due to the quartzite being "reflexed again and again in closely adpressed folds."*

In 1884 Professor Bonney communicated to the British Association meeting at Montreal a report "On the Archaean Rocks of Great Britain,"† in which special reference was made to the relations of the rock-groups in the North-West Highlands. He described the lithological and microscopic characters of the eastern gneiss in Glen Logan, and inferred that it is much more modern than the typical Hebridean rocks, and may possibly have been formed of their debris. He considered that the central Highlands consist of schists and gneisses, with some infolded masses of grit, quartzite, schistose and slaty beds, probably Palæozoic, and that the most recent classification of the crystalline rocks in the North-West Highlands would be as follows:—(*a*) coarse gneisses, Loch Maree series; (*b*) more variable bedded gneisses, Loch Shiel series; (*c*) mica-schists, quartz-schists and friable gneisses, Gairloch and Ben Fyn; (*d*) flaggy schists, Glen Docherty. He believed that after the deposition of the Palæozoic rocks of the north-west, an epoch of mountain-making ensued, the direction of pressure being north-west to south-east, which caused newer beds to be folded together and inversions or faults on a gigantic scale.

Selecting the region of Durness and Eireboll, Professor Lapworth mapped a large portion of it in great detail during the summers of 1882 and 1883. In the pages of the *Geological Magazine*‡ he published a series of papers on "The Secret of the Highlands," in which he described the geological structure of that region, confirming Nicoll's conclusions (1) that the Durness Limestone is the highest member of the Ordovician series (Lower Silurian,

* "Notes on Progressive Metamorphism," *Geol Mag.*, decade 3, vol. i., No. 5, p. 218.
† *Rep. Brit. Assoc.* for 1884, Reports, p. 529.
‡ "*Geol. Mag.*, new series, decade 2, vol. x., pp. 120, 193, 337.

Murchison), (2) that the "Upper Quartzite" and "Upper Limestone" are non-existent, (3) that there is no conformable sequence from the quartzites and limestones into the eastern gneissic series, (4) that the line of junction of the unaltered Palæozoic rocks is a line of fault and overthrust.

This author believed that the Highlands of Scotland include a portion of an old mountain system, formed of a complex of rock-formations of very different geological ages, which have been crushed and crumpled together by excessive lateral pressure, locally inverted, profoundly dislocated, and partially metamorphosed. In the area partly worked out by himself he recognised the stratigraphical phenomena to be identical in character with those developed by Rogers, Suess, Heim and Brögger in extra-British mountain regions.

In the Durness area he pointed out that the basal quartzite rests on the almost vertical edges of the Lewisian gneiss, followed by the pipe-rock. Next in order comes the limestone, which, though at first sight apparently of great thickness, is made up of a few distinct lithological zones, repeated by faults or inverted folds. From specimens collected by himself, and analysed by Dr. Tilden, F.R.S., he proved that many of the beds in the Durness basin are dolomites, and thus disposed of the classification advanced by Professor Heddle (see page 24). He further showed that the limestone is visibly overlain in clear sections and at a low angle by a series of wrinkled shales, micaceous flagstones and slaty schists, with intercalated zones of hornblendic gneissose schists; and even where transversely faulted against the limestone, this overlying series agrees precisely in dip, strike, and apparent amount of convolution. He pointed out that, as this physically overlying series is the upper flaggy gneiss of Murchison, it would appear at first sight that Murchison's theory of the sequence, so far as the Durness area is concerned, is absolutely impregnable.

Passing east to Loch Eireboll, Prof. Lapworth described the development of the zones overlying the pipe-rock (Fucoid Beds, Salterella Grit, limestone) on the headland of An-t-Sron and in the neighbourhood of Camas Bay, on the east side of that loch. He showed that the limestone is arranged in a syncline that stretches south to Eireboll House. Eastwards the basin is abruptly bent upwards, and the underlying strata emerge in descending order on the hill slope south-east of the An-t-Sron till we reach the thin conglomerate at the base of the quartzite that rests unconformably on the "igneous rock" (Sutherland gneiss). On the platform above the ridge there is a narrow island or outlier of quartzite surrounded by this crystalline rock or gneiss, and separated from it by a similar thin basal conglomerate, thus affording clear evidence of a distinct unconformability between the two series. The author discusses the principles of mountain structure, the development of overfolds and overfaults, the deformation of individual strata, and the defomation of mountain folds under the influence of horizontal thrust or earth-creep.

Subsequently, the results of his work, in so far as they affect the age, composition, and mode of formation of the eastern schists, were read by Professor Lapworth at a meeting of the Geologists' Association, July 4, 1884, and published in the following year,* the main points of which are here summarised.

In the district round Eireboll and Durness, the so-called Eastern (or Upper) Gneiss is composed of two distinct members. The older is the Arnaboll Gneiss, which is, in his opinion, the so-called Laurentian, brought up to the east of the Assynt (Durness-Eireboll) series by gigantic overfolds. The younger member is composed of the schistose metamorphic rocks of the Moine and Central Sutherland, and contains within it strips and patches of the lower zones of the Assynt (Durness-Eireboll) series. The schistose quartzites or quartz-schists of some authors are the crushed and mechanically metamorphosed ends of long wedges of the Assynt Series, and are often in visible continuity with the unaltered Assynt beds. The intermixture of Archæan and Assynt rocks is so complete that they can never be separated in the field, but must be mapped simply as metamorphic.

The planes of foliation and schistosity in the so-called Upper Metamorphic Series of Sutherland are not planes of bedding; but plains of cleavage or gliding planes, along which the rocks have yielded to the irresistible pressure of the lateral earth-creep during the process of mountain-making. Granites, syenites, pegmatites, gneisses, and quartzites have been crushed to powder, and have been finally flattened out into rocks, having all the external characters of hälleflintas and even finely laminated shales.

The process of rock-folding in the region is exceedingly complex. Folding, interfolding, buckling, shearing, stretching have all taken place again and again along the junction-plane between the sedimentary strata and the Archæan Series; and innumerable protrusions of igneous material have forced their way in numberless veins in the latter up to the former.

Schists composed of Archæan, Ordovician (sedimentary), and intrusive rocks respectively, form part of one and the same lowest (or heterogeneous) zone in the Eastern schistose area; but further east all recognisable distinctions vanish one by one, and in the present state of our knowledge all that we can presume to say is, that the schists of Central Sutherland are in all probability an intimate compound of sheets of (1) Archæan, (2) Sedimentary, and (3) Intrusive rocks, which have been crushed into slaty rock, wherein crystallisation has been set up along the cleavage planes.

In the Durness-Eireboll region there seems to be no trace of any sedimentary rock of more recent date than the Durness Limestone. The thin, so-called Upper Quartzite band of Sango Bay is the crushed basement zone of the Lower Quartzite. The green schists overlying it are pressure schists, formed and brought over in the great over-fault. The same zone occurs again in Eireboll along the great fault line of the Upper Schist Series.

* *Proc. Geol. Assoc.*, vol. viii., p. 438; also *Geol. Mag.*, new series, decade 3, vol. ii., p. 97 (1885).

The great area of metamorphic schists of Sutherland and the Central Highlands is, as a whole, neither Archæan nor Ordovician. The Sutherland (Arnaboll) gneiss is Archæan, but the Sutherland schist has been manufactured since Silurian times. One point seems clear, that the so-called oldest beds of the Highland succession of the Schistose Series of the North-West Highlands are the newest in point of time. The zone of intermixture and metamorphism (in Sutherland) travelled to west from east, and the last beds (schists) to be produced by the earth-movements are those now in contact with the Assynt Series in Durness, Eireboll, and Assynt.

Strikes, dips, and visible sequences are useless in these metamorphic rocks as indices of chronological sequence. The Highlands represent the remains of a degraded mountain-complex the newest of its component ranges being the fossil-bearing beds of the north-west. Some ranges were certainly in existence in the Highlands in Old Red Sandstone time, and some in Silurian time also and there can be little doubt that the Highland area has been the theatre of mountain-making again and again since then. If the same crumpling has taken place over its whole surface as has certainly taken place in Eireboll, its present width must be the merest fraction of its original extent, and the manufacture of its schists and gneisses may have gone on, in some localities, below its surface from pre-Cambrian time to the present without interruption.

At the close of his paper Professor Lapworth embodies his main conclusions under the following heads:—

1. That there is no recognisable chronological sequence (or invariable succession of superposition) in the metamorphic Highland area corresponding to that among sedimentary formations; for the planes dividing the truly metamorphic layers are not planes of deposition, but planes of shearing and cleavage.

2. Many of the Highland schists are composed of Archæan rocks, which have received their present pseudo-bedded arrangement since Ordovician (Silurian) time.

3. What proportion of these schists and gneisses is composed of Archæan, sedimentary, or intrusive materials respectively is in all probability an insoluble question.

4. The gneisses may be either Archæan or possibly formed by intrusion (injection of plutonic rocks) in later ages.

5. The schists may be composed either of crushed Archæan or crushed intrusive rocks, or of a mixture of these with sedimentary materials.

6. The so-called slates may be, according to the locality, either normal slates or crushed rocks, not yet crystallised, of either Archæan, sedimentary, intrusive, or of mixed origin.

In 1885 an important paper was published by Dr. Teall, "On the Metamorphosis of Dolerite into Hornblende-schist,"* 'as displayed by two more or less parallel dykes in the Archæan gneiss, near

* *Quart. Jour. Geol. Soc.*, xli., p. 133.

the village of Scourie, in Sutherlandshire. From a careful examination of the phenomena presented by the dykes in the field, and by microscopic sections of the rocks, he concluded (1) that the hornblende-schist has been developed from a dolerite by causes operating after the consolidation of the rock, and that the metamorphosis has been accompanied by a molecular rearrangement of the augite and the felspar; (2) that this molecular rearrangement has in certain cases taken place without the development of foliation; (3) that the plasticity which has led to the development of foliation is that due to high pressures at ordinary temperatures. These deductions have proved of great importance in interpreting many of the phenomena of the Archæan rocks.

The Geological Survey began the detailed mapping of the North-West Highlands in 1883 by tracing out the structure of the Durness-Eireboll region, which was completed in 1884. The results of their operations in the field led to the publication of a "Report on the Geology of the North-West of Sutherland," by Messrs. Peach and Horne with an Introduction by Sir Archibald Geikie, then Director-General of the staff, in which there was a frank abandonment of the view advocated by Murchison that the quartzites and limestones of the North-West Highlands are regularly and conformably overlain by the eastern schists. Evidence was adduced to prove the existence of overfolding, reversed faults, and powerful thrusts, whereby the Lewisian gneiss had been made to override the Silurian strata and the eastern schists had been driven from Eireboll for about ten miles westwards to Durness. The various proofs of dynamic metamorphism resulting from these terrestrial movements were briefly indicated, —the development of new divisional planes alike in the Lewisian gneiss, in the pegmatites, and in the Silurian sediments, the obliteration of the old structures and the appearance of new minerals.*

In 1888 a further report, based on the field notes and maps of Messrs. Peach, Horne, Gunn, Clough, Hinxman and Cadell, and containing detailed descriptions and illustrative sections of the results of the field work southwards to Loch Broom, was communicated to the Geological Society by Sir Archibald Geikie.†

Towards the close of 1888 Professor Lapworth announced the important discovery of the *Olenellus* fauna in the west of England.‡ Fragments of that characteristic genus had been found by him on the flanks of Caer Caradoc in 1885, but too imperfect for description. This determination was placed beyond doubt by the finding of further fragments in association with such Lower Cambrian forms as *Kutorgina, Acrothele*, etc. At the end of this paper three tables are given showing the classification of the Cambrian rocks in (1) North-western Europe; (2) the British Islands; (3) Central

* *Nature*, vol. xxxi., p. 29, Nov., 1884.

† *Quart. Jour. Geol. Soc.*, vol. xliv., p. 378.

‡ "On the Discovery of the *Olenellus* Fauna in the Lower Cambrian Rocks of Britain," *Geol. Mag.*, new series, decade 3, vol. 5, p. 484 (1888).

and South-western Europe, from which it will be seen that he correlated the strata containing *Salterella* and the *Archaeocyathus* fauna in Durness with the Cambrian system.

This correlation was confirmed in 1891 by the discovery of carapaces of *Olenellus* by the Geological Survey in the Fucoid Beds and Serpulite Grit in the Dundonnell Forest between Loch Broom and Loch Maree, which was announced by Sir A. Geikie at the British Association meeting at Cardiff in that year,* and described in a paper communicated to the Geological Society in 1892.† This discovery necessarily led to a change in the nomenclature of two of the great rock groups in the North-West Highlands. The series of red sandstones resting unconformably on the Lewisian gneiss were termed Torridonian after Loch Torridon, where Nicol showed that they are typically developed, and the unconformable series of quartzites, Fucoid Beds, Salterella grit, and limestone were now definitely included in the Cambrian system.

In 1894 further additions to the fauna of the *Olenellus* zone were described by Dr. Peach when he recorded the discovery of a new sub-genus, *Olenelloides*, and some new species of trilobites in the Fucoid Beds near Loch Maree.‡

In 1888 Mr H. M. Cadell communicated to the Royal Society of Edinburgh§ an account of certain experimental researches as conducted by himself, wherein he reproduced some of the remarkable structures so characteristic of the North-West Highlands, to which further reference will be made in Chapter XXXII.

The intrusive igneous rocks of the Assynt region, of later date than Cambrian time and yet older than the post-Cambrian movements, have been specially studied by Dr. Teall, who in 1892‖ described a new type of igneous rock—Borolanite—and in 1900 gave a preliminary account of the petrographical province comprising the plutonic complex of Cnoc na Sroine and Loch Borolan, and the various sills and dykes that traverse the Cambrian and Torridonian sediments, and even the underlying platform of Lewisian gneiss.¶

* *Nature*, vol. xliv., p. 479 ; *Rep. Brit. Assoc.* for 1891, Trans. of Secs., p. 633.

† "The Olenellus Zone in the North-West Highlands of Scotland," *Quart. Jour. Geol. Soc.*, vol. xlviii., p. 227.

‡ *Quart. Jour. Geol. Soc.*, vol. l. p. 661.

§ *Trans. Roy. Soc., Edin.*, vol. xxxv., p. 337.

‖ *Trans. Roy. Soc., Edin.*, vol. xxxvii., p. 163.

¶ "Nepheline-Syenite and its Associates in the North-west of Scotland," *Geol. Mag.*, new series, decade 4, vol. vii., p. 385.

Cliffs of Lewisian Gneiss, Cape Wrath, showing alternating bands of granite gneiss, with veins of pegmatite.

PART I.—THE LEWISIAN GNEISS.

SECTION I—GENERAL ACCOUNT OF THE GNEISS.

CHAPTER III.

CHIEF PETROGRAPHICAL CHARACTERS, DISTRIBUTION, AND STRUCTURE.*

In presenting a general summary of the Lewisian gneisses and schists along the western seaboard of Sutherland and Ross, attention will be directed, first, to the classification and main petrographical characters of these rocks as determined by Dr. Teall, and described by him in detail in Chapters IV.-VII.; and, second, to their distribution and structural relations as worked out in the field.

General Petrographical Characters.—The Lewisian gneiss of this region may be separated into (1) a Fundamental Complex, composed (*a*) mainly of gneisses that have affinities, both chemically and mineralogically, with plutonic igneous products, and (*b*) partly of crystalline schists, which may be regarded as probably of sedimentary origin; (2) a great series of igneous rocks intrusive in that complex, in the form of dykes and sills.

I. *Rocks of probably Plutonic Origin.*—Those members of the complex that have affinities with plutonic rocks contain, as their chief mineral constituents, olivine, augite, including diallage, hypersthene, hornblende, biotite, plagioclase, microcline, orthoclase, and quartz, which enter into the composition of peridotites, gabbros, diorites, and granites. The term gneiss is not strictly applicable to many of the members of this series, owing partly to their massive character and partly to the absence in places of mineral banding, but it is here adopted for the sake of convenience of description. The classification of these rocks, proposed in 1894 by Dr. Teall,† is based mainly on their mineralogical composition, but partly on their structure. From the subjoined table it will be seen that the classification of three of the groups is determined by the nature of the ferro-magnesian constituent, while a fourth

* By J. Horne.

† Annual Report of Geological Survey for 1894, p. 280; and for 1895, p. 17 of reprint.

is composed of ferro-magnesian minerals without felspar or quartz, and a fifth is characterised by the presence of both muscovite and biotite.

(I.) Rocks composed of ferro-magnesian minerals without felspar or quartz, comprising (A) peridotites, pyroxenites and banded hornblende rocks, (B) hornblende rocks not included in the banded series.
(II.) Rocks in which pyroxene is the dominant ferro-magnesian constituent, felspar always and quartz sometimes present. These include (A) rocks without quartz such as pyroxene-granulite, (B) with quartz, of which augite-gneiss is a representative type.
(III.) Rocks in which hornblende is the chief ferro-magnesian mineral, felspar being almost always present. These embrace (A) rocks without quartz or nearly so, and basic in composition, either massive (epidote-amphibolite or garnet-amphibolite) or schistose (hornblende-schist or -gneiss), and (B) with quartz, of which the granular hornblende-gneiss is an excellent example.
(IV.) Rocks in which biotite is the dominant ferro-magnesian constituent, both felspar and quartz being present, comprising biotite-gneiss proper and granulitic biotite-gneiss.
(V.) Rocks in which biotite and muscovite occur together with quartz and felspar ; muscovite-biotite-gneisses.

(I.) The ultra-basic rocks of the first group have only a limited development in the Fundamental Complex and are older than the more acid gneisses that enclose them. The hornblende rocks (I. B) are always associated with those containing pyroxene (I. A.).

(II.) The early basic members of the Complex are more largely represented than those of the ultra-basic series, and include, among other types, pyroxene-granulite and pyroxene-rocks resembling gabbros (II. A), together with garnet-amphibolite and epidote-amphibolite (III. A). Like the rocks of the first group, the early basic members are older than the more acid gneisses that surround them, and are usually banded and folded with the latter.

The pyroxene-gneisses with quartz form an important sub-division of the second group (II. B) and have a definite geographical distribution in the North-West Highlands. One of the most characteristic features is the blue quartz which they contain, and by means of which they can be readily identified. This ingredient resembles the blue quartz found in some of the metamorphic grits of the South-Eastern Highlands and in the basal Cambrian quartzites. These gneisses pass imperceptibly into the hornblende gneisses (III. B.) through the replacement of the pyroxene by hornblende.

Apart from the pyroxene gneiss, the hornblende-gneiss proper, with granular structure (III. B), is largely developed in the Fundamental Complex, and within well-defined limits. It is always banded, and the hornblende rarely shows idiomorphism, being frequently moulded on the quartz and felspar. This type often contains a green pyroxene as well as hornblende. These rocks are regarded as an intermediate series bearing the same relation to quartz-diorites that the pyroxene-gneisses do to the gabbros.

(III.) The granulitic types of the third group, in which hornblende is the chief ferro-magnesian constituent, are characteristic of the pre-Torridonian lines of movement or shear zones, to which attention will be presently directed. Indeed, in certain areas, as for instance, Rona, Raasay, and Poolewe, where the later basic dykes have been foliated, it is difficult in some cases to separate them from the foliated basic rocks of the original Complex.

(IV.) The biotite-gneisses embraced in the fourth group may have been formed in various ways. Some of them possibly represent altered sediments, some may be foliated granites, while others may have been derived by dynamic metamorphism from pyroxene and hornblende-gneisses. Those types in which biotite occurs in independent plates or aggregates, with a structure more or less granular, are associated with the granular hornblende-gneisses in certain districts. It is possible that some of the later foliated granites, especially in the area north of Laxford, may have been classed with the biotite-gneisses of the Fundamental Complex. The quartz of the biotite-gneiss contains many minute indeterminable inclusions, but shows no trace of the minute hair-like bodies so common in the blue quartz of the pyroxene-gneiss.

(V.) The muscovite-biotite-gneisses of the fifth group have also a well-defined distribution in the southern district. In some areas, as in Meall Rhiabhach, north of Loch Maree, they have undergone much dynamic metamorphism.

By means of a series of photographs of rock-structures taken in the field, the processes are illustrated in Chapter V. whereby the original members of the Fundamental Complex may have been developed, such as various stages in the separation of the acid and basic constituents, the differentiation in place of the felspathic and hornblendic elements, and the intrusion of the residual mother liquor, the gradual passage from a brecciated condition without parallel arrangement to a banded structure, and finally the inclusion of fragments of biotite-gneiss in a mass of similar material and the compression of the various members into parallel bands. It is inferred that, after the separation of the acid and basic materials, either by differentiation during fluxion or by separate intrusion, the members of the original complex must have been subsequently affected by plastic deformation.

II. *The Altered Sediments.*—The crystalline schists that have affinities with altered sedimentary rocks belong to several distinct types. They include (1) dark-brown platy schist; (2) silvery mica-schist, with idiomorphic garnets; (3) dark-grey granulitic biotite-schist; (4) graphitic schists, with black carbonaceous matter distributed in parallel folia throughout and actually traversing the hornblende, thus showing that the latter mineral had grown in place before being deformed; (5) quartz-magnetite-granulites, resembling the rocks of the Penokee iron-bearing series described by Irving and Van Hise; (6), the calcareous rocks, comprising limestone, dolomite, cipoline, with tremolite, chlorite, garnet, and epidote. These presumably altered sediments are restricted mainly to the Loch Maree district, and have only a limited development, as will be shown in the sequel.

III. *Later Intrusions (Dykes and Sills).*—The great series of igneous rocks intrusive in the Fundamental Complex, in the form of dykes and sills, may be arranged in four groups—(1) ultra-basic —picrites; (2) basic—comprising, among other types, hyperite, gabbro, diabase. enstatite-diabase, and epidiorite; (3) intermediate —microcline-mica-rocks, and biotite-diorite; (4) acid—granite and pegmatites. In the areas of unmodified gneiss, particularly in the district between Scourie and Loch Broom, the ultra-basic and basic intrusions preserve their dyke-like character, showing clearly that they rose along vertical or highly inclined fissures, after the development of the early banding or foliation in the gneisses of the Fundamental Complex. The trend of the basic dykes is usually W.N.W., that of the ultra-basic group more nearly east and west, and that of the granite sills and dykes generally W.N.W. The field-evidence proves the ultra-basic dykes to be later than the basic in the Assynt region, and the granite sills and pegmatites to have been intruded into the gneisses after the eruption of the basic dykes. (Plates II. and XXI.)

IV. *Effects of Pre-Torridonian Movements.*—The detailed mapping of the belt of country lying to the west of the post-Cambrian displacements has shown that, after the eruption of the ultra-basic, basic, and intermediate dykes, the whole area was in pre-Torridonian time subjected to earth movements which, affecting both the various members of the Fundamental Complex and also these later intrusions, gave rise to rapid plication of the strata and to lines of disruption or shear-zones, accompanied or followed by re-crystallisation of the original constituents, development of foliation, and occasional mylonisation of the rocks. The new planes of foliation are more or less parallel with the axial planes of folding, or with the planes of disruption.

These pre-Torridon lines of disruption and shearing generally run east and west or W.N.W., that is, approximately parallel with the dykes. Where the direction is east and west, the basic dykes are deflected, attenuated, and converted into hornblende-schist, while the original gneiss may be thrown into sharp folds, and undergo such a molecular rearrangement of its constituents as to become a granulitic gneiss. Similar effects have also been often produced in the reconstruction of the dykes and gneiss, when the trend of the movements has been toward W.N.W. the picrite dykes then passing into talcose schists. In connection with the basic intrusions it is of special importance to note that in the southern tracts, where the dykes are represented by hornblende-schists, which seem to become an integral part of the Fundamental Complex, and where intrusive junctions are only occasionally met with, biotite-gneisses and hornblende-gneisses are characteristically developed.

The granite intrusions, so well displayed north of Laxford, are likewise foliated, the parallel arrangement of the constituent minerals being chiefly marked by the orientation of the mica. In that region the field-evidence points to the conclusion that they cut the hornblende-schists, and that they were probably intruded before the violent plication of the gneisses. Cataclastic structures are usually absent, but the foliation may nevertheless be due to dynamic metamorphism.

V. *Distribution of the Fundamental Complex.*—A brief reference may here be made to the distribution of the Fundamental Complex throughout the region between Cape Wrath and Skye, to the structural relations of the altered sediments in that complex, and to the light thrown on the history of the Lewisian Gneiss by the various modifications of the later igneous intrusions. By the detailed mapping of the Survey, the members of the Fundamental Complex have been ascertained to present a more or less definite distribution. Hence the belt has been divided into three districts: the first extending from Cape Wrath to a line drawn between Laxford and Scourie, the second from near Scourie to Loch Broom, and the third from Gruinard Bay to Loch Torridon and the island of Raasay.

In the central district, from near Scourie to Loch Broom, the characteristic feature of the complex, in the unmodified areas, is the remarkable development of grey pyroxene-gneiss with the earlier ultra-basic and basic masses (pyroxenites, hornblendites, pyroxene-granulites, and garnet-amphibolites). As these rocks had been previously thrown into more or less gentle folds, the later basic and ultra-basic dykes can be traced through them with comparative ease. The lines of pre-Torridonian movement, with their folding, disruption and structural modifications of the gneiss and dykes, are likewise clearly displayed.

But in the district between Laxford and Cape Wrath the essential features of the complex are wholly different. Granular hornblende-gneisses and biotite-gneisses here prevail, while the pyroxene-gneiss with blue quartz is absent. The basic dykes are easily traceable, though partly in a foliated form, across the belt of ground that intervenes between Scourie and the great granite sills south of the Laxford river, but further north they appear in the form of bands of hornblende-gneiss, which can be followed only for short distances. Across the same belt also the gneisses begin to be folded on highly-inclined axes that strike north-west and south-east. The parallel lines of movement approach each other more closely until little of the pyroxenic gneiss is left unmodified. The structure of the gneisses now becomes granulitic, hornblende and biotite are the dominant ferro-magnesian minerals, and the hornblende presents a linear orientation. As the observer crosses the southern margin of the great sill-like intrusions of granite near Ben Stack, and advances northwards beyond Laxford to Loch Inchard, he finds the members of the Fundamental Complex to be either very coarsely granulitic or granular in structure; granular hornblende-gneiss, hornblende-biotite-gneiss, and biotite-gneiss proper being the chief types. Coincident with the appearance of these varieties of gneiss there is a great development of granite sills and dykes, which have been injected mainly along the early foliation planes of the gneisses. So minute, and at the same time so extensive, has been this intrusion of acid igneous material, that the members of the complex have been isolated in lenticles, while even *lit par lit* injection is not uncommon in certain localities. Hence it is sometimes difficult to separate the foliated granites or granite-gneisses from the biotite-gneisses proper. If what have been regarded as relics of basic dykes in some instances near Laxford, and even further north, are correctly interpreted, then the linear or plane-parallel foliation, which is characteristic of the dykes in the central and southern districts, has here been replaced by the short crystallisation that forms such a striking feature of the granular hornblende-gneisses over the northern district from Laxford to Cape Wrath and Loch Eireboll. But, perhaps, the short crystallisation may be regarded as a variety of the linear type.

These types of gneiss in the Fundamental Complex between Laxford and Loch Inchard and the plexus of granite and pegmatite intrusions continue north to Cape Wrath and Durness. At intervals the gneisses are thrown into gentle folds, while in other areas they are sharply plicated along highly-inclined axial planes that strike north-west and south-east. Few shear-lines or thrust-planes have been detected north of the great granite sills at Laxford.

In the southern district that stretches from Gruinard Bay to Loch Torridon and Raasay the rocks present certain distinctive features which differentiate them from those of the central and northern districts. From the former they are distinguished by the absence or comparative absence of the pyroxene-gneiss with blue quartz, and by the presence of biotite-gneiss, hornblende-biotite-gneiss, and granular hornblende-gneiss, resembling in certain areas the Laxford and Cape Wrath types. The rocks differ from those of the northern district in the abundance of the basic dyke-intrusions, which there appear either in the massive form or as hornblende-schists. Further, they differ from the rocks of the central and northern districts in the abundance of augen-gneisses, with biotite as the dominant ferro-magnesian constituent.

In the Gruinard part of the district, the Fundamental Complex is characterised by ultra-basic rocks (peridotites, pyroxenites, and hornblendites) and early basic masses, comprising diorites, garnet-amphibolites, and hornblende-pyroxene-granulites, which have only a limited development. The dominant type of gneiss, which is a grey acid rock with biotite and sometimes muscovite, invades and isolates the older ultra-basic and basic members. In this area the acid biotite-gneiss plays the same part as, in the Lochinver tract, the pyroxene-gneiss with blue quartz does to the older basic gneisses. In the northern portion of the district the banding of the grey gneiss is crude and irregular, and the basic dykes are then massive, though in the form of epidiorites, their intrusive character being well defined. It is noteworthy that the sequence of the later basic and ultra-basic intrusions that prevail in the central district (Assynt) seems here to be reversed; for the Fundamental Complex is intersected by some irregular dyke-like masses of ultra-basic material, while these are in turn cut by the basic dykes.

Southwards, from Gruinard, and to the west of the Fionn Loch, the basic dykes and acid biotite-gneiss are thrown into a great anticline, the axis of which runs north-west and south-east in the direction of Dubh Loch, near Carnmore. Along this arch the foliation of the gneiss is usually well-defined, and the dykes, now mostly in the form of hornblende-schist can be traced round the end of the arch. Advancing southwards from the Fionn Loch towards Loch Maree, we find the same type of acid biotite-gneiss, with its early basic masses and later dyke-intrusions arranged in a great compound syncline, which encloses one of the belts of altered sedimentary rocks above referred to. But even in certain areas beyond Loch Maree, as, for instance, in a triangular patch south-east of Creag Mhor Thollie, along the shore of that loch, and between Bad an Sgalaig and a point two miles north of Loch Torridon, it is still possible to separate with ease the augen-biotite-gneiss with the early basic masses from the later dykes. South of these limits, in Loch Torridon, in Rona, and in the north part of Raasay intrusive junctions are rare, and the later basic dykes appear as bands of hornblende-schist, which may be said to form now an integral part of the Fundamental Complex. Allusion may here be made to an example of the development of linear foliation and plane-parallel foliation alike in dykes and gneiss between Loch Maree and Gairloch, which is, perhaps, the finest instance along the whole belt from Cape Wrath to Skye.

South of Poolewe the members of the Fundamental Complex and the later basic dykes are thrown into a broad arch, the axis of which runs north-west and south-east, as is well shown on the map (Sheet 91). Before this anticlinal arrangement was developed the dykes and gneiss had been plicated on more or less highly-inclined vertical axes, the dykes being rendered schistose in part. The later system of folding, however. produced a complete rearrangement of the constituents both in dykes and gneiss. The latter rock consists there of augen-biotite gneiss, with ultra-basic and basic masses, traversed by basic dykes which show types of foliation that differ according as they have been developed on the crest or limbs of the arch. In the former case, where the basic dykes are nearly flat and still show intrusive junctions as they curve round the end of the anticline, linear foliation or "rodding" is developed, which is parallel with the pitch of the flexures. In the limbs of the fold, on the other hand, plane-parallel foliation appears alike in the dykes and gneiss, the planes common to both rocks dipping away from the anticlinal axis, that is, to the north-east and south-west. It would thus appear that differential movement of the constituents may be superinduced by folding, which may lead to partial or complete reconstruction of the dykes and gneiss, and to the development in them of common planes of schistosity.

On the shores of Loch Torridon and on both sides of Loch Shieldaig, biotite-gneisses, with some early basic masses, prevail, both being traversed by bands of hornblende-schist, representing the basic dykes. A large portion of the gneiss is there composed of a highly acid rock composed of quartz and felspar, like a foliated pegmatite. The members of the complex are folded on more or less highly-inclined axial planes striking north-west and south-east.

Again, in Rona and Raasay, the dominant member of the complex is biotite-gneiss with microcline, while hornblende-gneiss is not uncommon. The latter rock, where relative age is determinable, is the older of the two. Dark bands of hornblende-schist likewise occur, and are the only portions that can be separately mapped. Obviously they represent basic dykes, although they now appear as, apparently, an integral part of the complex. Pink and white pegmatites are there associated with the Lewisian gneiss, microcline being the characteristic felspar of the former and oligoclase of the latter.

VI.—*Distribution and Structural Relations of the Altered Sediments.*—Brief reference may now be made to the distribution and the structural relations of the altered sediments in regard to the members of the Fundamental Complex. Besides minor bands, two well-marked belts of these rocks stretch along the valley of Loch Maree, one on each side of the lake. They lie in compound synclinal folds of the Lewisian gneiss (Plate XXX.), and are traversed by a great sheet of hornblende-schist. (Ben Lair, near Letterewe, Sithean Mor, near Gairloch). The long axes of these compound synclines run north-west and south-east. The detailed mapping of this region has not furnished any clear evidence to show that the gneiss is intrusive in the altered sediments, but, in certain places, the two are so intimately associated as to suggest that such may have been the case. North of Loch Maree these sediments undoubtedly rest on a platform of acid biotite-gneiss with basic dykes, and are locally overlain by a part of the Fundamental Complex, consisting of biotite-gneiss with basic dykes in the form of hornblende-schists (Meall Riabhach). This overlying cake of gneiss reveals, under the microscope, cataclastic structures due to dynamic movement, and near its line of junction with the underlying sediments there are bands of mylonised rock. The superposition of the gneiss on the sediments is here due to folding and thrusting. It is obvious, therefore, that, whatever may have been the original relations of the sediments to the Lewisian gneiss, these have been modified by subsequent earth stresses, and that both have been affected by a common system of folding.

Along the line of complication between Eireboll and Skye overwhelming evidence has been obtained that slices of Lewisian gneiss were displaced and driven westwards by the post-Cambrian movement, as fully described in Chapter XXXII. That these isolated masses are in reality portions of the Archaean floor does not admit of doubt, for they include representatives of many of the characteristic types of gneiss to the west, with the later ultra-basic, basic, and acid intrusions, and in many cases are covered unconformably by the Torridon Sandstone and Cambrian strata.

Plate VI.

SECTION II.—PETROGRAPHY OF THE LEWISIAN GNEISS.

A. THE FUNDAMENTAL COMPLEX.

CHAPTER IV.

DETAILED ACCOUNT OF PETROGRAPHICAL CHARACTERS.*

In speaking of the geology of that portion of the north-west of Scotland which lies west of the zone of thrusting, it has become customary to use the term "Lewisian gneiss" for the rocks forming the old floor on which the Torridonian sediments were deposited. These rocks, however, vary in age and character, and they are not always gneisses in the ordinary petrographical sense. Detailed mapping has revealed the fact that the oldest group of rocks has been invaded by a set of later intrusions in the form of dykes and sills. These later rocks are in some cases clearly separable from the older complex; but in others they have been so modified by subsequent movements and so incorporated, as it were, in the older group, that the work of separation becomes extremely difficult, if not actually impossible. It is clear, therefore, that the Lewisian gneiss is not a geological formation in the ordinary sense of the word. Even if we exclude from it the later dykes and sills, there still remains a petrographical complex which future research will probably separate into its component parts. As matters stand at present, the pre-Torridonian rocks may be roughly grouped as follows:—

(1) Fundamental Complex.
(2) Ultra-basic dykes.
(3) Dykes and sills of dolerite (diabase), epidiorite, and hornblende-schist.
(4) A few dykes of exceptional composition.
(5) Granites and pegmatites.

Turning now to the Fundamental Complex, the first point to be noticed is that, notwithstanding its extreme petrographical diversity and the occurrence of a few exceptional types, the rocks, over the greater portion of the area in question, have decided affinities, both as regards chemical and mineralogical composition, with plutonic igneous products. They are mainly composed of olivine, augite (including diallage), hypersthene, hornblende,

* By J. J. H. Teall, written in 1894 and 1895.

biotite, plagioclase, microcline, orthoclase, and quartz; or, in other words, of the minerals which enter into the composition of peridotites, gabbros, diorites, and granites. Not only are the minerals the same as those of plutonic rocks, but the laws of paragenesis are also the same; and this is true, not only of the essential minerals above alluded to, but also to a great extent of the accessory constituents which do not form any large portion of the rocks. It is mainly when attention is paid to the distribution of the minerals in the rock-masses that the distinctive features of the complex become apparent. No one petrographical type is found to be persistent over any extensive area. Gradual or sudden changes in the relative proportions of the constituent minerals are almost everywhere recognisable. Some reference to what may be called the architectural features of the complex will be made after the rocks have been described, but at present it will suffice to refer to Plates VI. to XVIII.

Although, as a general rule, the rocks of the Fundamental Complex of gneiss and schist show decided affinities with plutonic igneous products, this is not always the case. Thus, as already mentioned, in the neighbourhood of Gairloch and Loch Maree, we find platy mica-schists, limestones, graphite-schist, and other rocks more or less resembling metamorphosed sedimentary deposits. It will be convenient, therefore, to separate the description of the rocks of the Fundamental Complex into two parts, and to deal first of all with those which have affinities with igneous products, and afterwards with the more or less exceptional rocks of the Gairloch and Loch Maree district. It must, however, be remembered that sediments of the arkose type approximate very closely in chemical and even in mineralogical composition to certain plutonic rocks, and that, in the process of metamorphism, the distinctive structural features may be lost. Some gneisses of really sedimentary origin may, therefore, be included in the group of rocks having affinities with plutonic rocks.

In any attempt to deal with these rocks from a petrographical point of view, we are met at the outset with the difficulty as to the use of the term gneiss. As ordinarily employed this term connotes not only a certain structure, but also a certain mineralogical composition. A gneiss should contain the same minerals as a granite, and also some form of parallel structure. Now, the Lewisian gneiss contains the mineralogical equivalents of biotite-granites, hornblende-granites, and augite-granites, as well as other rocks to which the term gneiss is mineralogically inapplicable.

The parallel structure implied by this term varies greatly in different cases. It may be due simply to the orientation of one or more of the constituents, or to a variation in the relative proportions of the different constituents in different layers. In the latter case, the banding may be on so small a scale as to be easily recognisable in hand specimens; or it may occur on so large a scale as to be only visible in the mass. When this is the case, hand specimens may appear perfectly massive; though, as a general rule, some trace of orientation of the constituents may be recognised.

In the biotite-gneisses other types of parallel structure may occur. Aggregates of biotite may form thin and more or less wavy films or "flaser." These films may be isolated in the quartzo-felspathic mass, or they may run together, thus separating the quartzo-felspathic portion of the rock into phacoids or lenticles. Such rocks are termed "flaser-gneiss" in Germany, and we may conveniently adopt the same expression. They are rare in the north-west of Scotland, where the gneisses are usually of the banded type.

In classifying the rocks either with reference to structure or composition, difficulties arise in consequence of transitions in various directions. Many schemes have been drawn up, and the following one, based primarily on mineralogical composition and, to a subordinate extent, on structure, has been finally adopted for descriptive purposes. Theoretical considerations have been excluded, so that, whatever views may be finally established as to the origin of this remarkable complex, it is hoped that the broad general facts will be found to have been correctly recorded.

I.—Rocks composed of ferro-magnesian minerals; without felspar or quartz.

- *A.* Peridotites, serpentines, pyroxenites and banded hornblende-rocks.
- *B.* Hornblende-rocks not included in the banded group.
  - (1) Those which consist of pale-coloured hornblende, occurring in confused aggregates.
  - (2) Those in which hornblende occurs as compact grains and prisms.
  - (3) Those in which anthophyllite is present.
    - (*a*) Anthophyllite-hornblende-rocks.
    - (*b*) Calc-anthophyllite rocks.

II.—Rocks in which pyroxenes are the dominating ferro-magnesian minerals; felspar always, and quartz sometimes, present.

- *A.* Without quartz, or containing it only as an unimportant accessory.
  - (1) Hypersthene-augite-plagioclase rocks.
    - (*a*) With garnet: pyroxene-granulite.
    - (*b*) Without garnet: rocks of the Baltimore-gabbro type.
  - (2) Augite-plagioclase-rocks.
  - (3) Augite-microcline rocks.
- *B.* With quartz.
  - (1) With hypersthene: quartz-bearing hypersthene-augite-plagioclase-rocks.
  - (2) Without hypersthene: augite-gneiss (proper).

III. Rocks in which hornblende is the dominating ferro-magnesian constituent; felspar almost always present.

- *A.* Without quartz, or containing it only in small quantity; rocks basic in composition.
  - (1) Rocks massive or only slightly foliated.
    - (*a*) Epidote-amphibolite.
    - (*b*) Zoisite-amphibolite.
    - (*c*) Garnet-amphibolite.
  - (2) Rocks foliated.
    - (*a*) Hornblende-schist or -gneiss.

Note.—Many of the hornblende-schists associated with the fundamental complex are foliated dykes.

B. With quartz : rocks intermediate or acid in composition.
(1) Rocks with compact hornblende and a granular structure : hornblende-gneiss (proper).
(2) Rocks with hornblende occurring in fibrous or other aggregates.
(3) Rocks with compact hornblende and a granulitic structure : granulitic hornblende-gneiss.

IV.—Rocks in which biotite is the dominating ferro-magnesian constituents ; felspar and quartz both present.
(1) Biotite occurring as independent plates or in aggregates of two or three large individuals : biotite-gneiss (proper).
(2) Biotite occurring in aggregates of smaller individuals.
(3) Biotite occurring as independent plates ; structure granulitic.

V.—Rocks in which biotite and muscovite occur ; quartz and felspar present.
Muscovite-biotite-gneiss.

In the following account of the petrographical characters of the Lewisian gneiss no reference will be made to the rocks of the Outer Hebrides. The descriptions apply only to the strip of country which is bounded on the one side by the zone of thrusting and on the other side by the sea. For purposes of reference this strip may be conveniently divided into a northern area, extending from Durness and Cape Wrath to Loch Laxford, a central area lying between Loch Laxford and Gruinard Bay, and a southern area, comprising the portion which lies between Gruinard Bay and the islands of Rona and Raassy.

1A. PERIDOTITES, SERPENTINES, PYROXENITES, AND HORNBLENDITES.

The ultra-basic rocks which occur as integral parts of the Fundamental Complex rarely contain a sufficient amount of olivine to justify the use of the term peridotite. They usually form more or less banded masses of pyroxenite and hornblendite.

The minerals entering into the composition of these banded masses are augite (including diallage), hypersthene, hornblende, olivine, magnetite, and a green spinel. Secondary hornblende, serpentine, and sometimes chlorite are found in the altered rocks. Scapolite was observed in one specimen (No. 1823) from Badcall, near Scourie.

The augite is pale green, in thin section, and without definite form. Sections out of the zone of the vertical axis give a maximum extinction of about 40°. In some specimens this monoclinic pyroxene is entirely free from inclusions and from any other divisional planes than those due to the ordinary prismatic cleavage; but, as a general rule, it contains parallel rows of very minute, dark brown, almost opaque plates and rods. One or more parallel rows may be present. When only one set is present, the inclusions are arranged parallel to the orthopinacoid. As a rule they are not uniformly distributed through the individual grains ; thus, the centre of a grain may be crowded with them, while the marginal part is perfectly free. In addition to these minute plates and rods we find grains of magnetite and green spinel also occurring as inclusions.

The pyroxene above described is precisely similar to that of the Baltimore gabbros described and figured by the late Professor G. H. Williams.* It is found not only in the rocks of the group now under consideration, but in all the other augitic rocks belonging to the Lewisian gneiss; it is, in fact, the characteristic monoclinic pyroxene of these rocks. A similar pyroxene occurs in a pyroxenite from Madagascar,† in the augite-norites (hyperites), and pyroxenites from the Cortlandt series on the Hudson River,‡ and in the anorthosite rocks of Canada.§

The hypersthene, which is almost always present in the banded pyroxenites, is easily distinguished from the monoclinic pyroxene by its strongly marked pleochroism. It occurs in irregular grains of approximately the same form and size as the green monoclinic pyroxene. The prismatic cleavages are often well-developed; and cross-sections, in which these cleavages intersect at right angles, show in convergent light the emergence of a positive bisectrix. Such sections give, for rays vibrating parallel to X, red; and for those vibrating parallel to Y, pale yellowish-brown to nearly colourless. Longitudinal sections, which are distinguished by parallel cleavage cracks, give straight extinction and appear green when viewed by rays vibrating parallel to Z. The pleochroism of this mineral, as a rule, is very intense, corresponding to the highly ferriferous variety for which Professor Judd proposed to revive Vom Rath's term, amblystegite.

Inclusions similar to those already described as occurring in the monoclinic pyroxene are occasionally found, likewise, in the hypersthene. This hypersthene is also similar to that occurring in the Baltimore gabbros.

Hornblende is rarely absent from the rocks under consideration. In some cases it occurs only as an accessory constituent; in others it is the only, or almost the only, ferro-magnesian silicate present. By the gradual increase in the amount of hornblende the pyroxenites pass into the hornblendites. Like the other constituents, the hornblende occurs in irregular grains and often contains parallel rows of minute rods or plates, arranged in one or more directions. The maximum extinction in the zone of the vertical axis is about 20°, and the colour scheme of a common variety is as follows:—X = a yellowish-green; Y and Z = dull dark green. In consequence of the absence of any colour differences for rays vibrating parallel to Y and Z, many sections show no dichroism.

* "The Baltimore Gabbros." *Bull. U.S. Geol. Survey*, No. 28, 1886.

† "Notes on the Petrographical Characters of some Rocks collected in Madagascar by the Rev. R. Baron." By F. H. Hatch. *Quart. Jour. Geol. Soc.*, vol. xlv., p. 340.

‡ "The Norites of the Cortlandt Series." By G. H. Williams. *Amer. Jour. Sci.*, vol. xxxiii., 1887, p. 135.

§ "Ueber das Norian oder Ober-Laurentian von Canada." F. D. Adams. *Neues Jahrbuch*, Beilage Band viii.. 1893, p. 419.

The colours of the hornblende in different specimens are not absolutely constant. Thus, in a variety from the neighbourhood of Dhrombaig (Drumbag) we find :—X, nearly colourless; Y and Z, brown; and in another, Lochan-an-Daimh, near Gruinard House, Ross :—X, pale greenish-yellow; Y, bright green; Z, bluish-green. There is no difference in the mode of occurrence of these different varieties; they all appear to be as much entitled to be regarded as original constituents as any other mineral present.

One other feature of the original hornblende deserves mention. The cleavages are often far less perfectly developed than is usual with this mineral. Dr. Hatch* has already called attention to this peculiarity of the hornblende in rocks of the type now under consideration.

Olivine is by no means so important or so constant a constituent of the rocks as the minerals above described. It is often entirely absent, and only in one or two specimens has it been found to occur in such abundance as to justify the use of the term peridotite. It occurs in colourless, irregular grains, which are traversed by the black veins of magnetite so commonly found in this mineral. It is often absolutely unaltered, but in a few specimens is more or less replaced by serpentine in the usual manner.

Magnetite and a dark-green spinel are almost invariably present in the banded pyroxenites. They occur independently of each other, and also in composite grains. The opacity of the spinel is often very great, so that the characteristic olive-green colour can only be seen in very thin sections. The natural opacity is also often increased by the presence of numerous minute black particles. Both magnetite and spinel are without definite crystallographic form.

As minerals which occur occasionally, biotite, apatite, and scapolite may be mentioned. Scapolite has been observed only in one specimen from Badcall, near Scourie (No. 1823), collected many years ago, before the mapping was commenced. The mineral occurs in irregular grains, which are crowded with minute opaque rods arranged, for the most part, parallel to the vertical axis. Isolated grains, when placed in a diffusion column, scatter themselves so that the lightest are seen to have a specific gravity of about 2·76. These contain fewer inclusions than those which float at lower levels. The abnormal specific gravity is, therefore, doubtless due to the inclusions. Treated with hot hydrochloric acid the grains show no change after three or four evaporations; a fact which points to the conclusion that the mineral is rich in the marialite-molecule. The characteristic cleavages are not seen in the thin sections, but can be readily developed by crushing the isolated grains. Sections at right angles to the vertical axis show the negative, uniaxial figure characteristic of scapolite.

The rocks in which the above minerals occur are black or dark-green in colour, and usually of medium grain. Although well banded on the large scale, the hand specimens frequently appear

* "A Peridotite from Kilamanjaro." *Geol. Mag.*, 1888, p. 257.

massive. Some idea of the nature of the banding may be formed from a consideration of the following sequence seen in a low projecting crag to the west of Scourie House. It must be remembered, however, that the rocks are not so sharply separated from each other as the use of two distinctive names may seem to indicate; pyroxene occurs in the hornblendites, and hornblende in the pyroxenites.

Hornblendite, - - - -	4 inches.
Pyroxenite, - - - - -	9 ,,
Hornblendite, - - - -	5 ,,
Pyroxenite, - - - - -	3 ,,
Hornblendite, - - - -	5 ,,
Pyroxenite, - - - -	1 foot 5 ,,
Hornblendite, - - - -	4 ,,
Pyroxenite, - - - - -	6 ,,
	4 feet 5 inches.

The bands of hornblendite are, as a rule coarser in grain than those of pyroxenite, and they are frequently crossed by transverse joints which appear as furrows on the weathered surface.

The rocks of this group form only a very small portion of the Lewisian gneiss. They may be studied at the locality above referred to; also on the south side of Loch an Daimh Mòr, about 1 mile south of Scourie; near Dhrombaig, east of Oldany Island; and at Lochan an Daimh, about 1½ miles E.N.E. of Gruinard House. The last mentioned locality is in Sheet 101; all the others are in Sheet 107. The most common varieties of the group may be termed olivine-hornblende-pyroxenites and hornblende-pyroxenites; but the Survey collection includes also hornblendites, olivine-hornblende-peridotites, and one specimen of dunite. The olivine-bearing rocks have often been more or less completely serpentinised.

IB. HORNBLENDE ROCKS NOT INCLUDED IN THE BANDED GROUP.

Rocks composed almost entirely of hornblendic minerals are found not only interbanded with pyroxenites, but also as knots, lenticles, and bands associated with felspar-bearing rocks. These may be roughly classified for purposes of description into three groups:—

(1) Those which consist of pale-coloured hornblende occurring in confused aggregates.

(2) Those in which the hornblende occurs in compact grains and prisms, usually dark-green in colour.

(3) Those in which the rhombic hornblende, anthophyllite, is present. These may be again sub-divided into :—

- (*a*) Anthophyllite-hornblende-rocks.
- (*b*) Calc-anthophyllite rocks.

(1) A specimen collected at the bend of the road near Loch Dhrombaig, and about ½ mile west of the village, may be taken as a type of the first group. This is a somewhat pale-green crystalline rock, composed almost entirely of a matted aggregate

of irregular individuals of hornblende. The outlines of the individuals are rarely well defined, but a tendency to the prismatic form may be occasionally recognised. A large portion of the slide consists of very fine-grained aggregates, which cannot be resolved into distinct individuals with definite outlines. Here and there larger patches, showing the cleavages of hornblende and giving fairly uniform extinction, may be observed. The whole of the hornblende is practically colourless in thin section. Iron ores occur in irregular patches and as small grains. In some places parallel rows of minute inclusions, precisely similar to those occurring as inclusions in the minerals of the pyroxenites, may be seen. (Plate XL., fig. 2.)

It is well known that diallage, hypersthene, and sometimes olivine give rise to hornblende, and in describing the ultra-basic dykes it will be shown that they occasionally become converted into rocks of the same character as those now under consideration. It is probable, therefore, that these rocks are metamorphic products, and that the hornblende is of secondary origin. The one selected as a type has probably originated from the alteration of pyroxenite, a rock known to occur in the immediate neighbourhood. In addition to hornblende and iron ore, the only other mineral present is chlorite. This forms small irregular patches wedged in between the other constituents. Its presence strengthens the view that the rock is a metamorphic product.

(2) In the second group of rocks the hornblende is entirely different in character. It is usually dark green in colour, and occurs in compact grains, which often interfere with each other so as to prevent the development of crystalline form. Sometimes, however, one grain is partially idiomorphic with respect to its neighbours and the forms $\{110\}$ and $\{010\}$ may then be recognised. It is this type of rock that so frequently forms knots and lenticles in the more acid gneisses. A specimen from the north-west of Rona (No. 5013, Plate XL., Fig. I.) may be taken as a type. It is a medium grained dark-green, almost black rock. The hornblende occurs in compact individuals occasionally showing the forms above mentioned. The colour scheme is as follows:—X, pale yellow; Y, green; Z, green with a tinge of blue. In addition to the hornblende there are some irregular patches of iron-ore and one or two flakes of biotite. Biotite is very often associated with hornblende in the black lenticles, and is sometimes as abundant as the hornblende itself.

Under this head we also refer certain rocks occurring near Cape Wrath which consist of radiating masses of actinolite, the prisms of which sometimes measure two or three inches in length.

(3) Anthophyllite is found in two very distinct types of rock. The one (*a*) is a dark-green, medium to coarse-grained, massive rock; the other (*b*) a pale grey, medium-grained rock containing a considerable amount of carbonate. In the former group (*a*) the anthophyllite occurs in association with ordinary green hornblende; in the latter it is, as a rule, the only representative of the hornblende-group of minerals.

Lumps of basic rock mainly composed of hornblende, separated by quartzo-felspathic material.
Cadha Beag, Little Gruinard, Ross-shire.

The specimen from Glac a Mhin Ath (about 700 yards N.N.W. of the north-west end of Caol Loch a' Mhin Ath, Sutherland, six-inch Sheet 31 S.E., 1 inch Sheet 107, 3419; Plate XLI., Fig. 1), is a moderately coarse-grained, black rock, composed of green hornblende, hypersthene, and a colourless mineral having the cleavages and prismatic angle of hornblende. Transverse sections of this mineral show the emergence of a positive bisectrix. Longitudiual sections give straight extinction. Cleavage flakes, produced by crushing the mineral, also give straight extinction and show the emergence of a negative bisectrix inclined to the plane of the flake. The optic axial plane is parallel to the brachypinacoid; which form, however, is not developed. The optic scheme is as follows:—a = X; b = Y; and c = Z; where a, b, and c represent the crystallographic axes, and X, Y and Z the axes of the ellipsoid of elasticity or optical indicatrix. These facts prove conclusively than the mineral in question is anthophyllite. It is developed in the prismatic form, and is idiomorphic with respect to the green hornblende.

Rocks of the above type are represented only by two specimens in the Survey collection, one from the neighbourhood of Rhiconich (1830), and the other from Glac a Mhin Ath (3419).

(*b*) The calc-anthophyllite rocks effervesce freely with cold dilute hydrochloric acid, and weather brown owing to the presence of some iron in the carbonate. A specimen from a point south of Allt Mor Geisgeil, two and a half miles south-east of Scourie (Sutherland, Sheet 107, No. 4651, Plate XLI., Fig. 2) may be selected as a type. The anthophyllite occurs as long slender prisms which lie in all directions in a matrix of crystalline, granular calcite. A few scales of hematite and grains of opaque iron-ore are also present.

When attacked by the weather these rocks develop a rough carious surface, owing to the removal of the calcite. They occur one mile N.N.W. of Achfarry (south-east slope of Ben Stack, No. 2723), and south-west of Creag Lochan-nam-Breac (about a mile east of Badcall Bay, south of Scourie), Allt Crom Geisgeil (4647). An allied rock is found at Creag Tombaca (south side of Loch Glendhu, about a mile and 300 yards E.S.E. from Kyle Sku Inn; No. 2955). In this case, however, the colourless prisms of anthophyllite lie in a matrix of pale brown mica, which is the dominant constituent. Calcite is present.

Little can be said as to the origin of the anthophyllite-bearing rocks, but it is worthy of note that a dyke in the Lewisian gneiss, ½ mile south-west of the outlet of Lochan na Bearta (Ross six-inch Sheet 46, north-east; one-inch Sheet 92, No. 5118) is essentially composed of green hornblende and anthophyllite, with some biotite, felspar (basic), and rutile. The anthophyllite occurs in long slender prisms bounded by the prismatic faces and a pinacoid truncating the acute angles of the prism. The main mass of the rock is formed of pale green hornblende, which occurs as large irregular grains, long prisms, and confused aggregates of minute individuals. The anthophyllite is idiomorphic with respect to the hornblende.

IIA. PYROXENE-FELSPAR-ROCKS, WITHOUT QUARTZ, or containing it only as an unimportant accessory.

The rocks of this group are essentially characterised by a pale-green, monoclinic pyroxene and felspar. With one exception (No. 2379) the felspar is allied to labradorite, and the rocks, therefore, resemble gabbros in composition. In the exceptional case the felspar is microcline, and the rock is, therefore, allied to the augite-syenites. The plagioclase rocks may be separated into two sub-groups, characterised by the presence or absence of hypersthene, and the first of these may be again sub-divided according to the presence or absence of garnet; but it must be remembered that this classification is more or less artificial and that the different groups shade into each other. Garnet is very irregular in its distribution, often abounding in one spot and disappearing within a few yards. The hypersthene-augite-plagioclase rocks (IIA. 1) may, so far as the hand-specimens are concerned, be divided into two main groups :—

(*a*) Garnetiferous hypersthene - augite - plagioclase rocks (pyroxene-granulites).
(*b*) Hypersthene-augite-plagioclase rocks (Baltimore gabbro type).

(*a*) The members of the first group are medium-grained, dark, crystalline rocks, with a variable amount of garnet. The presence of garnet alone distinguishes them from the rocks of the second group. They are closely connected also by intermediate varieties, with the pyroxenites on the one hand, and with the hornblende-pyroxene-gneisses on the other. The addition of garnet and felspar to the pyroxenites causes them to pass over into the group now under consideration. The minerals common to the two groups are precisely similar in character. Although not forming an important constituent, hornblende is often present. In addition to the compact variety, which may be either brown or green, there is sometimes found a more or less fibrous green hornblende, which is intimately associated with the pale green augite. This sometimes forms a ragged zone round the latter mineral, and sometimes occurs in irregular patches in the interior, as if replacing it. These phenomena are usually taken to indicate that this variety of hornblende is of secondary origin, and it may be so in this case. But whether this view be correct or not, it is certain that every stage in the apparent replacement of the green augite by this variety of hornblende may be observed, not only in the rocks of this group, but also in the pyroxene-gneisses which remain to be described. Indeed, the phenomenon is more perfectly exhibited in the last-mentioned rocks, and will again be referred to when these are described.

The felspar occurs, like the other constituents, in allotriomorphic grains. It is sometimes twinned on the albite and pericline plans, and sometimes unstriated. The twin lamellæ often die out in the middle of a grain; and in those rocks in which the felspar gives undulose extinction, indicative of strain, the lamellations appear to be, in part at least, of secondary origin. The plagioclase felspars of the rocks belonging to the fundamental gneiss range in composition from labradorite to oligoclase—the more basic felspars occurring in the more basic rocks. In the present group the felspars are allied to labradorite in composition.

The extraordinary freshness of the felspars, and, indeed, of all the minerals of the gneissose rocks is especially noteworthy. The grains are usually water clear, and only in rare cases show signs of turbidity or saussuritization.

The garnet is of a deep red colour and rarely, if ever, shows traces of idiomorphism. In this respect it offers a strong contrast to the garnets found in certain varieties of mica-schist. As already stated, it varies considerably in amount in different specimens, sometimes forming a large proportion of the rock, and at others sinking to the rank of an accessory constituent. The individual grains vary in size from microscopic particles to large masses measuring several inches across. In a few specimens the garnet forms narrow zones round the grains of iron-ore.

Biotite is occasionally present as an accessory constituent in the form of minute brown scales surrounding, or at least occurring in intimate association with the iron-ores. Magnetite, and less frequently pyrite, also occur as accessory constituents.

The hand specimens of the more typical varieties are devoid of foliation. They are neither banded nor do they show any parallel structure due to the orientation of the minerals. Under the microscope the structure is seen to be granular, with an occasional tendency to become granulitic. In the field they are intimately associated with the pyroxenites, and occur in the same districts. Most of the specimens in the Survey collection come from the neighbourhood of Scourie.

(*b*) The hypersthene-augite-plagioclase rocks, which differ from the above only in the absence of garnet, are dark, medium-grained, and usually massive in hand specimens. Both in structure and composition they are precisely similar to the gabbros of Baltimore, so well described by Prof. G. H. Williams.

A specimen from Strathan, 1¼ mile south-west of Lochinver Bay, near Loch Inver (3392), may be taken as typical of the group It is a dark, medium-grained, massive rock composed of augite, hypersthene, plagioclase, and magnetite, with pyrite and biotite as accessories. The augite belongs to the pale green variety already described, and occurs in grains averaging about 1mm. in diameter. The hypersthene is strongly pleochroic, and occasionally shows traces of idiomorphism in the prismatic zone. The felspar occurs in allotriomorphic grains of uniform dimensions in the different directions, averaging somewhat less than 1mm. in diameter. Many sections do not show twinning, and in those which do it is often seen to be impersistent. Undulose extinction is common, and the twinning is most marked in those which show this phenomenon. The specific gravity of the felspar is about 2.69. It was isolated in as pure a state as possible and analysed.

S_1O_2	53·98
Al_2O_3 - - -	27·85
Fe_2O_3 - - -	1·55
CaO - - - -	10·15
MgO - - -	tr.
K_2O - - - -	·29
Na_2O - - -	4·76
Loss on ignition - -	·64
	99·22

If we neglect the iron and loss on ignition and calculate to 100 we have:—

S_1O_2	55·64	55·4
Al_2O_3	28·69	28·5
CaO	10·46	10·4
K_2O	·30	—
Na_2O	4·91	5·7
	100·00	100·0

The figures in the second column correspond to the composition $Ab_1\ An_1$. The felspar is, therefore, on the border line between labradorite and andesine. It would be classed as the former by Tschermak, and as the latter by Dana.

The type rocks contain no hornblende, but this mineral occurs in many rocks which naturally belong to the group. It is similar to that occurring in the pyroxenites and granulites.

The specimens of this group in the Survey collection come from Strathan Bay, near Loch Inver, Rientraid, 2½ miles west of Kyle Sku, and north-west of Pairc-a-Chladaich, one mile north-west of Scourie. The rocks above described, though of considerable interest from a petrographical point of view, do not form a large portion of the fundamental complex. They occur rather as local and exceptional varieties. Those which remain to be considered are, as a rule, much more widely distributed.

(2) The augite-plagioclase rocks differ, so far as composition is concerned, from those of the last group merely in the absence of hypersthene, and from the pyroxene-gneisses in the absence of quartz. They are often massive in the hand specimen, but occasionally show traces of foliation due to the tendency of the augite and felspar to concentrate in thin and impersistent folia. The definite parallel banding so commonly seen in the hand specimens of the hornblende- and biotite-gneisses is not present in those portions of the complex in which augite is the dominant ferro-magnesian constituent.

A specimen from Strathan Bay, near Loch Inver (3406), may be selected as a type of the augite-plagioclase-rocks. It is a dark, medium-grained, massive rock composed of plagioclase, augite, and magnetite. The plagioclase belongs to the labradorite-andesine series. It is devoid of twinning except where the grains have been strained. In these places two sets of impersistent twin-lamellæ have often been developed at right angles to each other, reminding one to some extent of the cross-hatching of microcline. The pale green pyroxene is of the same type as that occurring in the pyroxenites, pyroxene-granulites, and hypersthene-augite-plagioclase rocks. In addition to the two ordinary cleavages it occasionally shows the structure of diallage and contains rows of minute, dark rods and plates, as well as scales of hematite. The magnetite is in irregular grains, like the other constituents, and often of considerable size. It is present in sufficient quantity to make the rock distinctly magnetic.

The mutual relations of the constituents are the same as those of typical gabbros with which these rocks have very close relations.

The principal deviations from the type above described depend on the occurrence of hypersthene, garnet, quartz, and original hornblende as accessory constituents. These represent passages into the other groups. In one or two instances uralitic hornblende has been formed at the expense of the augite. The best specimens in the Survey collection come from the neighbourhood of Loch Inver; but the type is probably not uncommon in the extensive region characterised by the pyroxene-gneisses.

(3) The last type under the present head is represented only by one specimen from Polla, near the head of Loch Eireboll (2379); but it is so remarkable as to deserve a somewhat detailed description. It is a moderately coarse-grained, massive rock, essentially composed of microcline and a green pyroxene. Hornblende, sphene, apatite, quartz and magnetite occur as accessories.

The dominant constituent is microcline. It occurs in irregular individuals which often measure 2mm. in diameter. There is no trace of alteration, and the cross-hatching is very perfectly developed. The pyroxene is also allotriomorphic. It is green in colour, but the tints are more vivid than those of the augite of the rocks above described. The extinction is that of normal augite, not that of ægirine. The mineral is probably an ægirine-augite. The accessory minerals form only a small portion of the mass. The hornblende is green and similar to that of the hornblende-gneisses. Sphene, apatite, and quartz all occur as irregular grains. The magnetite shows traces of idiomorphism. This rock, if igneous, would be termed augite-syenite.

IIB. PYROXENE-FELSPAR ROCKS, WITH QUARTZ.

The Lewisian gneiss between Scourie and Loch Inver, and for some distance both north and south of these localities, is largely composed of quartzose pyroxene-gneisses. These rocks frequently show a marked foliation due to the presence of streaks and ill-defined bands of dark and light colour. The principal ferro-magnesian constituent is the green, monoclinic pyroxene; but hypersthene, biotite and original hornblende occasionally occur. Garnet is also sometimes present.

The felspar, in all cases examined, is some variety of the andesine-oligoclase series. In unstrained individuals twinning is usually absent, but in those which give undulose extinction impersistent lamellæ may frequently be observed. Much of the twinning is certainly of a secondary character. In the case of a rock from Duartmore Bridge, between Kyle Sku and Scourie, the felspar was definitely determined by analysis to be andesine corresponding to the formula $Ab_4\ An_3$.

The quartz occurs in large irregular individuals, and is remarkable for the bluish, opalescent tinge which enables one to recognise it easily in the hand specimens. In the foliated rocks the grains are often tabular in form; but the direction in which the grains are flattened has no relation to the crystallographic characters of the mineral. Under the microscope this blue quartz, which is so characteristic of the pyroxene-gneisses, is always seen to contain minute inclusions. These are of four types:—(1) rows of minute dots; (2) extremely thin hairs formed, in all probability, of the same substance as the dots; (3) cavities with very dark borders; and (4) minute irregular flecks and grains.

A similar blue quartz occurs in the grits of the Southern Highlands, and there also it contains the minute hairs and rows of dots. As inclusions of this character are absent from the quartz of the hornblende and biotite-gneisses, which does not show the blue colour, it seems probable that this colour is due to the inclusions.

The other minerals of these rocks are precisely similar to those of the rocks already described.

Cataclastic structures are not uncommon. The effects of pressure on the felspar—undulose extinction and secondary twin lamellation—have been already referred to. These effects are even more marked on the quartz, where they consist of undulose extinction, an irregular striping, seen only under crossed nicols, and partial granulitization.

The specimens in the Survey collection may be separated into two groups, corresponding to the two main groups of the pyroxene-plagioclase rocks, the one being characterised by the presence, the other by the absence, of hypersthene. Seeing that gneissose structures are almost always recognisable in the hand-specimens, these may be termed:—

(1) Hypersthene-augite-gneiss.
(2) Augite-gneiss.

A specimen from the shore of Loch Glencoul at Unapool (3397) may be taken as a type of the first group. It is a dark rock traversed by streaks of grey material, which occasionally die out within the limits of the hand-specimen.

The green pyroxene occurs in irregular grains which measure 1 mm. or less in diameter, and are usually of equal dimensions in the different directions. More rarely they are flattened in the direction of foliation and are then five or six times longer than broad. Several grains usually occur in juxtaposition, and the aggregate is elongated in the direction of foliation.

The hypersthene belongs to the strongly pleochroic variety (amblystegite). It also forms irregular grains, and is associated with the augite. The felspar presents the characters already described. Quartz occurs as irregular grains, and also as small rounded inclusions. It does not form an important constituent, and is limited to the lighter portions of the mass. Magnetite and apatite occur as accessories.

The other specimens of the group differ from the one selected as a type principally in the relative proportions of the constituents, and in the extent to which cataclastic structures have been developed. The two pyroxenes seem capable of replacing each other to almost any extent. In some specimens augite is the dominant ferro-magnesian mineral; in others hypersthene. Again there are great variations in the relative proportions of the ferro-magnesian and the quartzo-felspathic constituents. The tendency of these two groups to separate is seen in almost every exposure, and just as hand specimens, composed entirely of ferro-magnesian minerals, may be obtained (pyroxenites), so also may hand specimens entirely composed of quartzo-felspathic constituents be procured (3405).

In one specimen, referred to in this group, from the roadside north of Badcall Church, Scourie (2989), garnet is present in considerable amount. This is merely a quartz-bearing variety of pyroxene-granulite. It illustrates the fact that each variety of rock described under IIa., has its corresponding representative under IIb.

The second group of rocks differs from the first only in the absence of hypersthene. It is well represented by a specimen taken from a point west of Pairc-a-Chladaic, Scourie (4889). This is a moderately coarse-grained, grey rock of typical gneissose structure. The quartz is abundant and occurs in lenticular folia, which are distinctly recognisable on a weathered surface. There is no marked banding in the hand specimen; but the two principal constituents, quartz and plagioclase (oligoclase-andesine), occur in folia. Augite is recognisable in the microscopic slide, but is not abundant. Some of the augite has been replaced by uralitic hornblende.

The rocks of this group pass over into Group IIIb., 2, by imperceptible gradations in consequence of the replacement of augite by hornblende. Two specimens, in which this replacement has more or less taken place, have been analysed by Mr. Wilson.

	I.		II.
SiO_2 -	54·86	-	60·39
Al_2O_3 -	17·3	-	16·14
Fe_2O_3 -	2·25	-	3·56
FeO -	7·43	-	3·88
MnO -	·17	-	·86
CaO -	7·45	-	6·36
MgO -	3·97	-	3·43
K_2O -	1·06	-	·87
Na_2O -	3·27	-	3·75
Loss on ignition	1·76	-	·91
	99·52		100·15
Sp. Gr. -	3·02	-	2·77

I.—Garnet-quartz-pyroxene-gneiss, north of Loch Beannach, north-west of Little Assynt (7842) This rock is without any well-marked parallel structure, but the constituents are somewhat unequally mixed. It is composed of augite, uralitic hornblende, plagioclase, quartz, iron-ores, and garnet. There is also a little dark brown biotite occurring in aggregates of small scales. It is an intermediate form between IIB. and IIIB. 2.

II.—Quartz-pyroxene-gneiss, north-west of wood, Loch-a-Bhaid-Daraich, Scourie (7841). This rock shows a well-marked parallel banding. The same constituents are present as in the last, with the exception of garnet. The ferro-magnesian constituents are less abundant, and there is more secondary hornblende. The augite forms cores in the hornblende-aggregate. This rock might equally well be placed with IIIB. 2.

Owing to the extreme petrographical diversity of the Lewisian gneiss as a whole, it is difficult to determine the average composition of the complex. No system of sampling can be devised which will give a reliable result. The general impression left after the examination of rocks from the whole of the area under review is that if the mass were uniform it would be of intermediate composition, not, perhaps, very different from that represented by the second of the above analyses.

As already stated, the pyroxene-gneisses are the dominant rocks between Scourie and Loch Inver. Most of the specimens in the Survey collection come from the neighbourhood of Scourie and Kyle Sku.

IIIA. HORNBLENDE-FELSPAR ROCKS (BASIC).

Rocks into which hornblende enters as the principal ferromagnesian constituent, in association with felspar, or with felspar and quartz, play a very important part in the composition of the Lewisian gneiss. They vary considerably in character, and doubtless owe their origin to various causes. In the present condition of knowledge it is by no means easy to formulate or apply any scheme of classification based on genetic principles. The rocks will, therefore, be

Basic Hornblende-Gneiss traversed by quartzo-felspathic veins. Cadha Beag, Little Gruinard, Ross-shire.

described without reference to their mode of origin. They are partly basic and partly intermediate in composition; the former answering to basic diorites and epidiorites, the latter to quartz-diorites and hornblende-granitites. It will be convenient to take the basic division first.

The basic hornblende-plagioclase rocks may be divided, according to structure, into those which are massive or only slightly schistose (amphibolites) and those which are markedly foliated. The two are often intimately associated, so that one and the same mass may be an amphibolite in its centre and a hornblende-schist or gneiss on its margins.

The typical amphibolites consist of hornblende and a saussuritic aggregate of felspar and epidote or zoisite. Some rocks which resemble the amphibolites contain garnet with or without epidote. These will be classed as garnet-amphibolites. A somewhat serious difficulty arises from the overlapping of the terms amphibolite and epidiorite. The general plan hitherto adopted is to use the term amphibolites for the basic hornblende-felspar rocks (with or without a mineral of the epidote-group) which cannot be separated from the fundamental complex, and the term epidiorite for the corresponding rocks which belong to the later basic intrusions. But this plan has its disadvantages, for some of the modified dyke-rocks are indistinguishable from rocks described under the present head as epidote-amphibolite, It would, perhaps, be more satisfactory to limit the term epidiorite to those rocks which show traces of the original igneous structure; but even this would not be free from difficulty in consequence of the innumerable passage-forms. The facts can best be described without attempting to give rigid definitions to the terms.

In addition to the two principal constituents, the amphibolites usually contain epidote, zoisite, or garnet. The hornblende is pale green in colour and usually shows a bluish tint when viewed with rays vibrating parallel to Z. It often occurs in fibrous or other aggregates, and when present as compact grains the outlines are, as a rule, very irregular. The felspar either forms a mosaic, with or without quartz, or else occurs in irregular patches, which give uniform extinction over large areas and interlock with each other, so as to form a kind of ground-mass in which grains and crystals of epidote or zoisite are often scattered. The aggregates of felspar and zoisite or epidote answer to the description of saussurite given by Cathrein.* Iron-ores, sphene, and chlorite occur as accessory constituents.

The typical amphibolites are dark-coloured, medium-grained, massive rocks. They differ from normal igneous rocks in the mutual relations of the different minerals and in the frequent presence of epidote or zoisite.

One of the most remarkable masses of amphibolite in the district occurs at Cnoc-an-Sgriodach, 1½ mile E.N.E. of the village of Stoer (3409, Plate XLIII., Fig. 1). It is devoid of foliation

* *Zeitsch. f. Kryst.* Band VII., 1883, p. 234.

over a large area and might, at first sight, be taken as a normal igneous product. The hornblende individuals show, under the microscope, a marked tendency to elongation in the direction of the vertical axis, and traces of crystalline faces in the prismatic zone may be recognised; but the terminations are always ragged. The rudimentary prisms lie scattered in all directions in a saussuritic aggregate of andesine and epidote. This mass of epidote-amphibolite contains patches and veins of a white, granular rock, composed almost entirely of andesine.

The distinction between epidote and zoisite in the amphibolite is not always satisfactory, because one and the same grain will sometimes show marked variations in the strength of the double-refraction. But the Survey collection includes two specimens of typical zoisite-amphibolite; one from Sango Bay (2345) near Durness, and the other from Lochan nam Breac Buidhe, Eireboll (2415, Plate XLIII., Fig. 2). Both are fine-grained, somewhat foliated rocks, composed of green hornblende and saussurite. The rocks are mottled in consequence of the unequal distribution of the saussurite and hornblende. Under the microscope the saussurite is seen to be a fine-grained aggregate of zoisite and felspar. The hornblende is fibrous or uralitic.

The garnet-amphibolites are dense, dark green, medium-grained rocks in which the garnet is very irregularly distributed. They are often intimately associated with the garnetiferous hypersthene-augite-plagioclase rocks, out of which they have probably been formed by the uralitization of the pyroxenes and the saussuritization of the felspar.

In addition to the amphibolites we frequently find bands of basic, foliated, hornblende-felspar rocks associated with the hornblende and biotite-gneisses of the northern and southern portions of the area under consideration. These agree very closely in composition and sometimes also in structure with the foliated portions of the later basic intrusions, so that in regions where the complex has been affected by powerful earth movements, since these intrusions, as, for example, in the district south of Poolewe, it becomes difficult to separate the early from the later basic material.

The region between Laxford and Durness is very largely composed of hornblende-gneiss. The darker and more basic portions of this gneiss are essentially composed of hornblende and a plagioclase belonging to the labradorite-andesine series. A pale green pyroxene, epidote, and sphene not unfrequently occur as accessory constituents. Garnet is also sometimes present. One or two examples of the group will now be referred to.

A specimen from Cape Wrath (2992) is of medium grain, and almost black. The rock is composed of green hornblende, more or less altered plagioclase, a pale green pyroxene, sphene, iron-ores, apatite, and epidote. The hornblende is compact, and gives no evidence of secondary origin.

Another specimen, $\frac{1}{3}$ mile E.N.E. of Badcall store house, Loch Laxford, 1 inch Sheet 107 (3475), contains numerous small red garnets, and shows a more definite separation of the ferro-magnesian and felspathic constituents. The felspar occurs in small lenticular granulitic patches, which may have originated by the granulitization of larger individuals. This rock differs from a garnet-amphibolite only in the presence of a slight foliation.

Both the specimens here referred to contain pyroxene; but there are several others which do not contain this mineral. Thus a specimen from the shore at Torran, in the northern part of the Isle of Raasay (5846), is a moderately coarse-grained, dark, basic, foliated rock, composed of hornblende and plagioclase, with biotite and sphene as accessory constituents.

In the southern part of the area, between Gairloch and Loch Maree, on Loch Torridon, and in the islands of Rona and Raasay there are many bands of hornblende-schist which appear to form an integral part of the Lewisian Gneiss. Here and there, however, clear evidence of their original intrusive character may be obtained, and it is probable, therefore, that, in the majority of cases, they belong to the series of later basic intrusions.

IIIB. HORNBLENDE-FELSPAR ROCKS, WITH QUARTZ.

The remaining rocks in which hornblende is the dominating ferro-magnesian constitutent may be most conveniently subdivided according to the character of the hornblende and the structure of the rocks.

1. Rocks with compact hornblende and a more or less granular* structure. Hornblende-gneiss (proper).
2. Rocks with hornblende occurring in fibrous or other aggregates.
3. Rocks with compact hornblende and a more or less granulitic structure. Granulitic hornblende-gneiss.

The typical varieties of these three groups are well-defined; but, as so frequently happens when any large number of rocks has to be dealt with, cases arise in which it is by no means easy to say to which group a particular specimen should be referred. The rocks with compact hornblende and a granular structure (Plate XLII., Fig. 1) are especially characteristic of the northern and southern areas, that is north of Loch Laxford and south of Loch Broom. They graduate on the one side into the pyroxene-gneisses and on the other into biotite-gneisses.

The rocks with hornblende occurring in fibrous or other aggregates (Plate XLIV., Figs. 1 and 2) are common in the central zone in which the pyroxene-gneisses abound, and they are connected with these in such a manner as to suggest that the hornblende is in many, if not in all cases a secondary product after pyroxene.

The rocks with compact hornblende and a more or less granulitic structure (Plate XLV., Figs. 1 and 2) are especially characteristic of

* The term granular refers only to the relations of the constituents. The rocks are always foliated; often banded.

the narrow zones in which shearing has taken place. The rocks of the three groups will now be described in the order mentioned above.

(1) The minerals of the first group are hornblende, pyroxene, biotite, felspar, quartz, epidote, iron-ores, sphene, and apatite.

The hornblende rarely shows any traces of idiomorphism. It is frequently moulded both on the quartz and on the felspar. In many rocks rounded grains of quartz occur as inclusions. The characteristic cleavages are well marked, and twinning of the common type may sometimes be seen. The colour is somewhat variable, both as regards tint and intensity, but it is always some shade of green. The colour schemes of two common types are as follows:—

X	Y	Z
Yellowish green.	Green.	Dark green.
Greenish yellow.	Green.	Bluish green.

Pale green pyroxene of the type found in the pyroxene-gneisses is sometimes present as an accessory constituent. It is always sharply defined from the hornblende. Whatever may have been the condition under which the rocks assumed their present form, the one mineral is as much entitled to be regarded as an original constituent as the other. Inclusions of pyroxene may sometimes be seen in the hornblende, but the junctions are always sharply defined. The pyroxene never resembles an unaltered core, as it so often does in rocks belonging to the second group.

Biotite is found in the more acid members of the group. It is present in well-defined plates. The basal plane is developed, but the mineral is without definite crystallographic outlines in the prismatic zone. In sections parallel to the vertical axis the colour for rays vibrating parallel to this axis is yellowish brown, and for rays vibrating at right angles to this axis deep brown. The pleochroism is very strongly marked, and the absorption is so great in the case of rays vibrating at right angles to the principal axis that the mineral is nearly opaque in ordinary sections.

Different varieties of felspar are present in different rocks. The more basic members of the group contain a variety allied to labradorite; while the more acid members contain oligoclase and sometimes also orthoclase or microcline. It is not, however, until the biotite-gneisses are reached that potash felspars are at all common. The mineral always occurs in irregular grains, and twinning is sometimes present, sometimes absent. The alteration when present is always of the micaceous type.

Quartz occurs in the form of rounded grains and irregular patches. It is sometimes moulded on the felspar, but occurs also, in the form of rounded grains, as inclusions in the felspar and hornblende. The hair-like inclusions, so characteristic of the blue quartz of the pyroxene-gneisses are entirely absent.

Epidote is sometimes present. It occurs as irregular grains and occasionally as more or less idiomorphic crystals. Although in some cases undoubtedly a secondary product, in others it is as much entitled to be regarded as an original product as any other mineral present. This is especially the case with certain varieties of gneiss found in the neighbourhood of Laxford Bridge (4471). The idiomorphic epidotes are not as a rule elongated in the direction of the orthodiagonal axis; but occur in crystals of about equal dimensions in the different directions. The forms {100} {001}, and {$\bar{1}$01} are common in the zone of the orthodiagonal axis and terminal faces, if, indeed, they may be so called, seeing that there is no marked elongation of the individuals, may also be recognised, but not easily identified. Cleavages parallel to {001} and {100} occur, and the characteristic pleochroism is strongly marked.

Colourless epidote, quite distinct from the above, arising as a consequence of saussuritization, may be seen in some specimens (4437).

The other minerals occur only as unimportant accessories. Iron-ores are represented by magnetite and pyrite. Sphene is by no means uncommon. It occurs as aggregates of colourless and often spindle-shaped grains (2390 Plate XLII., Fig. 2); less frequently as detached grains which are sometimes coloured. Apatite is occasionally found as short stumpy prisms, or as irregular grains.

The rocks, as a rule, are remarkably fresh, but the felspars occasionally show the micaceous type of decomposition, and chlorite sometimes occurs as a consequence of the alteration of the ferro-magnesian constituents.

The rocks are medium to coarse in grain, and vary considerably in the relative proportions of the different constituents. Although corresponding, as a rule, to plutonic rocks of intermediate composition they merge on the one side into basic, and on the other into acid rocks. There is also considerable diversity as regards the extent to which parallel structure is developed. This is more or less recognisable in all the specimens; but it may vary from a vague orientation of the minerals in a rock of uniform composition to a well-marked banding in which the ferro-magnesian and quartzo-felspathic constituents have been concentrated along definite layers. The foliation is generally of the plane-parallel type; but the linear type may be observed in districts where "mullion-structure" is prominent.

This type of rock is so widely distributed in the northern and southern areas that it is scarcely nececessary to mention any special areas. It may be well studied near Durness, at Poolewe, and in the islands of Rona and Raasay. The principal varieties may be designated by such terms as hornblende-pyroxene-gneiss (3476, 2390), hornblende-biotite-gneiss (1836, 2378, 3474), and hornblende-epidote-gneiss (4474).

(2) The hornblende of the second group of rocks does not occur in compact masses, but as aggregates (Plate XLIV., Figs. 1 and 2). The individuals of which these aggregates are composed vary considerably in size. In the interior of a patch they are usually small and intimately associated with grains of quartz. Sometimes calcite

is present, but this is rare. The peripheral portions of a patch are usually formed of larger grains than the central parts, and with these larger individuals quartz is not associated (Plate XLIV., Fig. 2). The above must be regarded as the more common mode of occurrence, but sometimes the grains forming the interior portions of a patch are uniformly orientated, or even connected up with hornblende-substance, so as to constitute one individual, in spite of the great number of minute and more or less rounded grains of quartz. This is the micro-poikilitic structure of Williams.

The outlines of the patches of hornblende are irregular, and the adjacent mineral, whether quartz or felspar, accommodates itself perfectly to these outlines. The hornblende of these rocks is identical with that of the gabbro-diorite of Williams. An interesting question arises, therefore, as to the relation of this form of hornblende to the pyroxene of the pyroxene-gneisses. The rocks are found in the same area as the pyroxene-gneisses. Moreover, pyroxene is sometimes present; and when this is the case, the relations of the pyroxene to the hornblende are such as to suggest that the latter mineral is of secondary origin. Thus the pyroxene occurs as cores in the aggregates of hornblende (855, 4468); its outlines are ragged and ill-defined, and there is, as it were, a blending of the two minerals, so that it is often difficult to say where one ends and the other begins.

It thus appears that there is a marked contrast between the hornblende of these rocks and that of the hornblende-gneisses of the northern and southern areas. In the latter the hornblende occurs in the compact form as individuals of considerable size, and although it occasionally contains one or two rounded grains of quartz these never occur in such numbers as to produce the typical micro-poikilitic structure. Moreover, the relations between pyroxene and hornblende are quite different in the two cases. In the one pyroxene appears to shade off gradually into the hornblende-aggregates; in the other the two minerals are always sharply separated, and both are compact.

Biotite is very frequently present as a constituent of the rocks now under consideration. Like the hornblende it occurs in aggregates—not in isolated flakes of considerable size. The small flakes are brown or reddish brown in colour; in fact the mineral, both in its character and mode of occurrence, more closely resembles that of contact rocks than that of normal igneous products. The aggregates of biotite are usually associated with those of hornblende, and bear the same relation to the adjacent quartz and felspar.

The felspar is similar to that of the pyroxene-gneisses. It is generally fresh and free from inclusions, but occasionally contains prisms of colourless epidote. Decomposition of the micaceous type has, in a few instances, given rise to turbidity.

The quartz is precisely similar to that of the pyroxene-gneisses, and contains the same hairs and rows of dots. The other minerals which do not call for detailed description are magnetite, pyrite, sphene, and apatite. They are not always present, and, when present, occur only as unimportant accessories.

The rocks bear the closest external resemblances to the pyroxene-gneisses with which they are associated, and into which they pass by imperceptible gradations. So close is this resemblance that it is almost impossible to distinguish in the field between the two groups. They are of medium grain and generally grey in colour; but the constituents are rarely distributed uniformly through the mass, and, of course, the colour varies with the relative proportions of the different constituents. A more or less well-marked parallel structure due to concentration of the black and white constituents along planes or folia can generally be detected. This parallel banding is not, however, so well defined as in the normal hornblende-gneisses. The folia are not so persistent, and their boundaries are less sharply defined.

It thus appears that as regards distribution, general aspect, character of the foliation, and the nature of the quartz, these rocks are intimately related to the pyroxene-gneisses. Taking all these facts into consideration, as well as the peculiar relation of the pyroxene and hornblende in certain specimens, it seems impossible to avoid the conclusion that they have been formed from the pyroxene-gneisses by secondary metamorphic processes.

The general distribution of the rocks has already been referred to. The Survey collection includes good examples from Unapool, near Kyle Sku (853), Scourie (849), a promontory in Loch Maree, 3½ miles south-east of Poolewe (4187), and 200 yards north-west of the bridge over the Inver, Loch Inver (4461). Specimens containing cores of pyroxene come from Scourie (853) and from Craig-a-Mhail, north of Scourie Bay (4468).

(3) The typical rocks of the third group differ in a most marked manner from those of the other two. They are grey in colour, fine in grain, granulitic in texture, and split readily into thin slabs.

The hornblende is compact, and the individuals are often elongated in the direction of the vertical axis. Along with this goes a tendency to idiomorphism, so that the forms {110} and {010} may be frequently recognised. Inclusions of quartz sometimes occur in the central portions of the larger individuals (Plate XLV., Fig. 1). The pleochroism is similar to that in the group last described:—X yellowish green, Y green, Z bluish green. Twinning parallel to the ortho-pinacoid is sometimes present. In some rocks the mineral occurs as long prisms (Plate XLV., Fig. 1); in others as grains of fairly uniform dimensions (Plate XLV., Fig. 2).

Brown biotite may be present as small, thin, isolated plates; epidote as minute crystals and grains; iron-ores as grains and crystals of magnetite or pyrite, and more rarely as thin plates of ilmenite. Sphene and rutile sometimes occur as accessories. The above constituents lie in a granulitic mosaic of quartz and felspar (Plate XLVI., Fig. 1).

When the hornblende is developed in long prisms the contrast between the crystals of this mineral and the constituents of the ground-mass is very striking; but when this form is absent the individuals approximate in size to those of the ground-mass, and the rock then becomes a typical hornblende-granulite (4454, Plate XLV., Fig. 2). The foliation is plane-parallel, with a tendency in some specimens to the linear type.

Rocks of this type are especially characteristic of the narrow shear-zones which traverse the Lewisian gneiss, and which are indicated on the one-inch map by opaque yellow lines. As bearing on their origin, a specimen, selected by Mr. Clough (3454) "to show the old broad planes of original foliation in contact with the newer and thinner planes developed in a pre-Torridonian slide," will be more fully described. It comes from the west-end of Loch na-h-Airidh Sleibhe [Sutherland, 6-inch Sheet 39, north-east, 1-inch Sheet 107]. One portion is a dark, medium-grained rock with bands due to a variation in the relative proportions of the darker and lighter coloured constituents. The limits of the bands are not sharply defined, but they are sufficiently distinct to leave no doubt as to the structure of the rock. Under the microscope this portion is seen to be composed of oligoclase, quartz, hornblende, and biotite, with iron-ores and apatite as accessories. The quartz and felspar are related to each other as in many granitic rocks. Sometimes the oligoclase shows a slight tendency to idiomorphism, and is more or less turbid in consequence of alteration. The hornblende is of the porous, spongy type found in the last group of rocks. The biotite is also similar in colour and mode of occurrence to that found in the same group; but the individuals are somewhat larger.

Another portion of the same specimen is foliated in a direction nearly at right angles to that of the part just described. The folia are thinner, and the micro-structure of the rock is different. The constituents are felspar, quartz, hornblende, and iron-ores (magnetite and pyrite); with epidote as an accessory. The hornblende occurs in grains which are sometimes elongated in the direction of the vertical axis, and when this is the case the individuals are arranged with their longer axes more or less parallel to the planes of secondary foliation. There are a few large turbid individuals of felspar which sometimes show traces of idiomorphism, *but the bulk of the quartz and felspar forms a typical granulitic mosaic.*

There is no hard and fast line between the two varieties of rock. The direction of foliation changes rapidly, and along with this change in direction goes the change in structure of the rock. The moderately coarse granitic structure, as seen in the relation of the quartz and felspar of the one variety, passes over into the fine granulitic structure as seen in the relation of the same two minerals in the other.

A change of this kind is frequently seen, not only in the gneiss, but also in the dykes which cut the gneiss. As it occurs in both rocks, notwithstanding their difference in age, along narrow zones which shift the dykes as faults and which give independent evidence of having been zones of shearing, it is supposed to owe its origin to secondary dynamic causes. It is worthy of note that this change from a granitic to a granulitic structure is unaccom-

Hornblende-Gneiss with veins of pegmatite, showing transition from brecciated condition on left to banded condition on right. Ard Shieldaig, Loch Torridon.

panied by those evidences of fracture and trituration which are invariably associated with the development of mylonites. The difference in the two cases is probably due, as Professor Judd has suggested,* to differences in the temperature and pressure under which the deformation was effected. In the one case (granulitization) the straining of the rock produces molecular and in the other (mylonitization) molar displacements.

It follows, as a necessary consequence of the above view as to the origin of the granulitic hornblende-gneisses, that the grains of quartz and felspar should not be uniformly distributed through the granulitic mosaic. Lenticular folia of quartz should alternate with corresponding folia of felspar; the grains of each separate folium representing collectively one of the larger individuals of the granular aggregate. Such a mode of distribution of quartz and felspar may frequently be observed. Thus in the typical hornblende-granulite (4454, Plate XLV., Fig. 2), the quartz-felspar mosaic is formed of narrow lenticular folia. This cannot be distinctly seen in ordinary light, because both minerals are colourless and occur in grains of about the same size. But if the slide be uncovered and treated, first with hydrofluoric acid and afterwards with fuchsine-solution or some other staining medium, the separate folia of quartz and felspar can be easily distinguished (Plate XLVI., Fig. 2). Typical examples of granulitic hornblende-gneiss may be observed on the roadside west of Loch-an-h'Irinne, Clachtoll, near Loch Inver (4454); 250 yards north of the bridge over the Inver, near Loch Inver (4450); at Loch-an-Eun, 1½ miles E.N.E. of Loch Inver (3740); and many other localities in Sheet 107.

IV. ROCKS IN WHICH BIOTITE IS THE DOMINATING FERRO-MAGNESIAN CONSTITUENT; FELSPAR AND QUARTZ BOTH PRESENT.

If biotite-gneiss be defined as a foliated crystalline rock, composed of biotite, felspar, and quartz, it includes rocks formed in many different ways. Taken in this broad, general sense, it is one of the most widely distributed rocks in the Highlands of Scotland. But it may be in one place a foliated granite, in another a granite modified by dynamic action, in a third a part of a gneissose complex, and in a fourth a metamorphosed grit in which all the original clastic characters have disappeared. Even this does not exhaust the list of the possible modes of origin of biotite-gneisses, for there is good reason to believe that many rocks of the Central Highlands, to which the term is applicable, have originated by the metamorphism of argillaceous sediments.

The pre-Torridonian rocks of the north-west of Scotland contain representatives of at least two of the above groups. Mr. Clough has shown that in the neighbourhood of Laxford Bridge there are numerous intrusions, often of a sill-like character, of gneissose-

* "On static and dynamic metamorphism." *Geol. Mag.*, ser. 3, vol. vi., pp. 243-249.

granite. These belong to the first or second groups—possibly they contain representatives of both. Biotite-gneisses also enter into the composition of the fundamental complex, especially in the northern and southern areas. These constitute the third group, which may be subdivided very much in the same way as the hornblende-gneisses:—

1. Rocks with biotite occurring in independent plates or aggregates of two or three large individuals. Structure more or less granular. Biotite-gneiss (proper).
2. Rocks with biotite occurring in aggregates of small scales.
3. Rocks in which the biotite occurs as more or less independent plates; structure granulitic.

(1) The minerals of the first group are biotite, oligoclase, alkali-felspar, and quartz, with epidote, orthite, apatite, and sphene occurring as accessories. Hornblende and pyroxene sometimes occur in passage varieties, indicating transitions into groups already described.

Biotite, which is the distinctive mineral of the group, though by no means the most abundant, occurs in independent plates or in aggregates of two or three large individuals which mutually interfere with each other. The basal plane is often well-developed, but the boundaries in the prismatic zone are usually irregular and often very ragged. The pleochroism is strongly marked. The usual colour is brown; but a green variety is sometimes present.

The felspars include oligoclase and an alkali felspar which usually presents the structure of microcline. Oligoclase occasionally, though rarely, shows a faint tendency to idiomorphism; microcline is invariably interstitial. The felspars have suffered but little from alteration. A slight turbidity due to the micaceous type of decomposition may occasionally be seen in the oligoclase, but the microcline is always water-clear.

In the typical rocks of this group the boundaries of the felspar are more or less rounded, and lobes of quartz project into this mineral. Rounded grains of quartz also appear to occur as inclusions; but these may be sections of lobes so cut as not to show he connection with adjacent quartz. This is the "quartz de corrosion" of French authors. It occurs in granites, and therefore serves to connect the biotite-gneisses of this type with plutonic igneous rocks.

The quartz, which is abundant, contains many minute, indeterminable specks and flecks; but the hair-like bodies, so common in the blue quartz of the pyroxene-gneisses, are absent. Liquid inclusions have not been observed.

The hornblende and pyroxene, when present, are precisely similar to the minerals of the hornblende and pyroxene-gneisses. Epidote is often visible and appears, in most cases, to be an original constituent. It occurs as irregular grains and more or less perfect crystals. The pale yellowish-green variety sometimes contains a kernel of deep brown orthite (5858, 5893). Epidote, as is well known, is frequently formed, together with chlorite, by the alteration of ferro-magnesian constituents, and instances of this mode of origin are not wanting in the group of rocks now under consideration; but there are many other cases, as for example when epidote occurs in perfectly fresh biotite, which cannot be explained in this way. Again the occurrence of cores of orthite tells in favour of the original character of some of the epidote.

Apatite is commonly present, but never in any quantity. It forms grains or thick prisms with rounded angles. Iron ores are, as a rule, absent.

The rocks are, for the most part, medium grained grey gneisses, which often show a well-marked parallel banding. One or two specimens referred to in this group may possibly belong to the later granitic gneisses; but pink gneisses, which cannot be separated from the fundamental complex, occur in some localities, as for example in the north of Raasay. As a rule there is no marked difference in size between the different constituents, but [illegible] augen-gneiss occurs on a limited scale in the island of Rona. It contains large, lenticular crystals of pink orthoclase in Carlsbad twins.*

A specimen from ½-mile east of Sangobeag (8128). [illegible] composed of biotite, microcline, oligoclase, and quartz with accessory hornblende, was analysed by Mr. Wilson with the following result:—

S_1O_2	-	-	66·76
Al_2O_3	-	-	14·38
Fe_2O_3	-	-	2·04
FeO	-	-	3·75
MnO	-	-	·14
CaO	-	-	4·62
MgO	-	-	2·71
K_2O	-	-	3·[illegible]
Na_2O	-	-	1·4[illegible]
Ignition	-	-	·4[illegible]
			[illegible]
Sp. Gr.			[illegible]

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Bad na
ond (5515);

The group, as a whole, is intimately [illegible] (1991); and hornblende-gneisses. By an increase [illegible] Maree (4661). a decrease in the amount of hornblende [illegible] developed on the pass into hornblende-biotite-gneisses [illegible] och and Ben Lair. gneisses. Along with this change [illegible] profoundly modified amount of alkali-felspar and quartz. [illegible] active characters of the

Biotite-gneisses of the above [illegible] in the hand specimens, the north of Laxford, and [illegible] parated from each other as

* Mr. Clough has ob[illegible] [illegible]en-central-alpen." *Abh. d. Akad.* Loch Maree district.

Specimens from the west side of the Kyle of Durness (2384), from a point one mile south of Rhiconich (4475), and from Beinn-na-h'Iolaire, north portion of Raasay (5909, 5910), may be referred to as typical examples. The two specimens from the last-mentioned locality illustrate the extreme variability of the group so far as the relative proportions of the different constituents are concerned. The one is a dark rock rich in biotite, the other a light-coloured rock almost entirely composed of quartz and felspar.

(2) The rocks of the second group in which biotite occurs in aggregates of small scales are intimately related to those of the second group of hornblendic rocks (III. B2). They occur in the same district and pass into the rocks of that group by imperceptible gradations. The biotite occurs in aggregates of reddish-brown or greenish scales. The reddish-brown variety, both in character and mode of distribution, is very similar to that of many contact rocks. Felspar occurs in irregular grains and may be either striated or unstriated. The mean refractive index is higher than that of oligoclase, and no difference can be detected between the average refractive indices of the striated and unstriated sections. In a specimen from one mile north-east of Cnoc Odhair, south of Scourie (4445), the felspars show a fibrous structure. The included fibres have a lower refractive index than the felspar which surrounds them, and the structure is therefore probably due to an intergrowth of two felspars, not of felspar and quartz; in other words, it is microperthitic, not micropegmatitic.

Quartz occurs in irregular grains and granular or granulitic aggregates. It resembles the quartz of the pyroxene-gneisses and contains the thin hair-like bodies and rows of dots. Iron ores are invariably present, and apatite may usually be recognised.

The rocks are medium grained, grey or brown gneisses, and they resemble the pyroxene-gneisses in the character of their foliation. The brownish tint of many of these rocks is due to the biotite. The intimate connection between these rocks and the pyroxene-gneisses has already been referred to. They contain the same variety of quartz, occur in the same areas, and possess the same structure. Biotite of the same type has already been described as occurring in the second group of hornblendic gneisses, which therefore occupy an intermediate position between the pyroxene-gneisses and the rocks now under consideration. A specimen from Craig a Mhail, on the north side of Scourie bay (4447), may be taken as typical of the group.

(3) The third group consists of granulitic biotite-gneisses. These rocks are developed in the shear-zones under the same conditions as the granulitic hornblende-gneisses. A typical specimen from a point 20 yards south-west of Loch nan Eun, near Loch Inver (4449), is composed of small scales of biotite, grains of epidote, and a granulitic mosaic of quartz and felspar. In general appearance it may be described as a grey, laminated granulite, differing only from the hornblende-granulites in containing biotite instead of hornblende. The slabby mode of fracture characteristic of the granulitic rocks is well marked.

Other specimens contain hornblende as an accessory. The derivation of these rocks from others of a coarser and more granular structure is often clearly traceable in the field.

V. ROCKS IN WHICH TWO MICAS ARE PRESENT, TOGETHER WITH QUARTZ AND FELSPAR.

Muscovite-biotite-gneiss.

Rocks answering to the above definition form a somewhat variable group. They are found in the southern area, between Gruinard Bay and Loch Torridon.

Three more or less distinct types, which will be referred to as the (*a*) Cabeg type (Cadha Beag—at the bend of the road, ½ mile north-west of Little Gruinard), (*b*) the Meall Riabhach (a hill one mile north of Rhn Noa pier at the head of Loch Maree) type, and (*c*) the Ben Dearg (a hill three miles N.N.E. of Torridon House) type, may be recognised.

(*a*) The rocks of the Cabeg type may be either banded (5509) or fairly massive, with only faint indications of parallel structure (4661). White mica is by no means conspicuous, either in the hand-specimens or in microscopic sections. The constituents are oligoclase, microcline (sometimes absent), biotite, muscovite, and quartz, with epidote, sphene, and apatite as accessories. The special feature of this type is the occurrence of large, irregular grains of oligoclase crowded with minute, idiomorphic crystals of epidote. Dr. E. Weinschenck has described and figured a similar occurrence of epidote (zoisite) in the oligoclase of the Gross Venediger.* He regards the mineral as an original product of the granitic magma.

Microcline, when present, is always subordinate to the oligoclase. Quartz occurs in large grains containing liquid inclusions. Biotite forms flakes of considerable size, several of which usually occur together. Muscovite occurs in well crystallised flakes, but never in abundance. Epidote is found not only as inclusions in the felspar, but also as grains of considerable size in association with the biotite. Sphene and apatite are present as unimportant accessories. This type occurs 300 yards west of the summit of the Cabeg road, south of Gruinard Bay (5509); near Loch Bad na Cuileg, south of Little Gruinard, in the same neighbourhood (5515); south of Loch na Curaich, 2 miles W.S.W. Poolewe (4991); and at Creag Mheall Mhor, on the north-east side of Loch Maree (4661).

(*b*) Gneisses of the Meall Riabhach type are developed on the north-east side of Loch Maree, between Ben Slioch and Ben Lair. The region is one in which the rocks have been profoundly modified by dynamic action; and many of the distinctive characters of the group are the result of this action. Thus, in the hand-specimens, the constituents are not, as a rule, sharply separated from each other as

* "Beiträge zur Petrographie der östlichen-central-alpen." *Abh. d. Akad. d. Wiss., München*, xviii.

they are in most of the rocks already described, in which the dynamic action has been either anterior to or simultaneous with the crystallisation. The explanation of this macroscopic character is furnished by microscopic examination. The larger constituents are seen to lie in a matrix of secondary crush material.

A typical specimen of the group from Leth Chreag. about half-way between Letterewe and Loch Garbhoig, is mainly composed of oligoclase, microcline, and quartz (4429), with some biotite, muscovite, and epidote. Crush-structures are strongly marked and affect all the constituents. The larger grains lie in a secondary matrix, mainly composed of quartz, but containing also crushed felspar and muscovite. The original quartz grains have been drawn into lenticles and "flaser" with the development of micro-crystalline and even crypto-crystalline material.

Another specimen from the west side of Leth Chreag burn (4432) is a pinkish gneissose rock containing "eyes" and long spindle-shaped folia of microcline. It shows marked linear foliation and is intermediate between "augen-gneiss" and hälleflinta-like mylonites, both of which occur in the same district.

(*c*) The rocks of the Ben Dearg type show a well marked plane-parallel foliation. White mica is abundant, and gives the characteristic silvery lustre to the flat surfaces of schistosity. The constituents are microcline, oligoclase, quartz, biotite, and muscovite. Traces of cataclastic structure may be observed in some specimens. The type rocks come from Ben Dearg, three miles N.N.E. of Torridon House, Loch Torridon (4356, 4357, 4358); but similar rocks occur north of the bend in Allt Coire nan Dearcag, 1½ miles N.N.E. of Ardlair, Loch Maree (Sheet 92, 5484), and about ⅔ mile north-west of Carnmore old house, four miles N.N.E. of Letterewe, Loch Maree (5216).

In addition to the rocks above referred to there are others which do not fall readily into the above scheme of classification. There are, for example, granulitic muscovite-biotite-gneisses resembling in structure the rocks of the shear-zones (5486); highly schistose rocks containing much silvery white mica (5113); and gneisses containing thin lenticular folia of quartz which project on the weathered surface (4406, 4339). Micas are not conspicuous in the last mentioned group, which is in other respects allied to the gneisses of the Ben Dearg type.

CHAPTER V.

ARCHITECTURAL FEATURES OF THE FUNDAMENTAL COMPLEX.*

The principal varieties of rock entering into the composition of the Fundamental Complex have now been described. It remains to give some account of the way in which they are associated so as to build up the complex; or, to use an expression introduced by Prof. Brögger, of the architectural features of the mass. As these features have been described in other portions of the Memoir, it will suffice, in this connection, to call attention to the more important points.

The fact that no one type of rock occurs over any large area has already been referred to. Variations in the relative proportions of the different constituents are almost everywhere noticeable, and there is great diversity in the mode of association of the different varieties of rock.

If we leave out of account the rocks of supposed sedimentary character, the most striking features of the complex are due to the mode of association of lighter and darker varieties; that is, of rocks rich in ferro-magnesian minerals and others rich in felspar and quartz. The primary cause of the architectural features is that which produced a heterogeneous mass wherein the ferro-magnesian and quartzo-felspathic constituents were unevenly distributed. After a complex of this kind had been formed, either by differentiation, or by the intrusion of more acid into more basic material, or to both of these operations combined, the secondary and more striking features were undoubtedly determined by plastic deformation.

In wandering over the region of Lewisian gneiss in the north-west of Scotland, it is impossible to avoid being forcibly impressed with the resemblance between the architectural features of the rocks and the forms and dispositions of the foam-flecks on the pools of comparatively still water below falls and rapids. In the spaces where little or no movement is going on, irregular and rounded masses of foam are separated by dark areas of still water. On the margins of these spaces, where movement is in progress, they are drawn out first into lenticles and then into thin streaks which may remain parallel or be bent, by subsequent movements, into serpentine folds or complicated convolutions which defy analysis, and resemble the damascening of old sword-blades and gun-barrels.

* By J. J. H. Teall.

Every type of structure thus produced on the surface of the water can be matched in the rocks of the district: but it is the dark varieties that correspond to the white foam and the lighter coloured varieties to the dark water. It must, of course, be remembered that the disposition of the foam represents, in two dimensions of space, the results of complicated movements taking place in the mass of the water in three dimensions; and so also with the appearances seen on any plane surface of rock. If the water were heterogeneous instead of homogeneous, and if the freezing points of the different portions were different, then progressive cooling would undoubtedly result in the formation of a solid mass having the architectural features of many portions of the Lewisian gneiss. Similar features may be observed in the banded gabbros of Skye, Rum, and elsewhere.

Some of the principal types of architecture are represented in the photographs of rock-surfaces (Plates VI. to XIV.); but a very much larger number of photographs would be required to give an adequate idea of the almost endless variety which occurs in nature. In Plate VI. the lighter felspathic and the darker hornblendic portions are imperfectly separated or imperfectly mixed, according to whichever view is taken as to the origin of the heterogeneous mass. In Plate VII. the separation is more marked, and lumps of basic hornblende rock are seen to be separated by white quartzo-felspathic material. Are the phenomena represented in these two photographs to be explained by differentiation in sitû, or by the intrusion of acid into basic material? They appear to favour the former hypothesis. The portion represented in Plate VIII. also shows a fairly sharp separation between the felspathic and hornblendic portions. In this case, veins of quartzo-felspathic material cut across the foliation of basic hornblende-gneiss, and the appearances favour the intrusive as opposed to the differentiation hypothesis. But in truth the two hypotheses are not necessarily opposed, for if the differentiation were accompanied by the concentration of the first formed ferro-magnesian constituents round local centres (Plate VII.), and if the basic portions were the first to solidify, then the still fluid mother liquor would be free to act as an intrusive magma in relation to the first formed basic rock.

Plate IX. introduces another set of phenomena. It illustrates the rapid but gradual passage from what may be termed a brecciated condition, devoid of parallel structure, to a banded condition in which that structure is strongly marked. The left-hand portion of the exposed face is very similar to that seen in Plate VII.; the right-hand portion is composed of the same materials in the form of a banded hornblende-gneiss.

In this particular case the phenomena are complicated by the occurrence of quartzo-felspathic material of two types, belonging to two distinct periods. The lighter patches and streaks, intimately associated with the darker masses, are rich in plagioclase, and were probably formed from the magma out of which the darker masses consolidated; but, on the extreme right, are two masses of foliated pegmatite containing large lenticular crystals of

Fragments of banded Hornblende-biotite-gneiss in more acid material: a plutonic breccia.
Near Creag Mhor Thollie, Poolewe, Ross-shire.

microcline, one of which is clearly recognisable in the photograph. Now, in other regions—as, for example, near Laxford Bridge—the microcline-pegmatites are obviously associated with gneissose granites which have been intruded into the rocks of the Fundamental Complex. They belong to a late phase in the history of the pre-Torridonian rocks, and are usually unfoliated. The occurrence of similar pegmatites in the region in which the photograph was taken (Loch Torridon) showing strong foliation probably indicates a deformation of a later date than that which converted the brecciated mass into a banded hornblende-gneiss.

Plates X. and XI. represent an extremely interesting variety of brecciated structure discovered by Mr. Clough. Fragments of banded and contorted hornblende-biotite-gneiss are enclosed in a mass of similar material, much poorer in ferro-magnesian constituents. Flow-structure round the margin of one of these fragments is clearly seen in Plate XI. The mass represented in these photographs may be regarded as the plutonic equivalent of a brecciated rhyolite, so far as structure is concerned.

One general law of considerable importance is brought out by an examination of these photographs, and becomes still more prominent when the rocks are examined in the field. Whenever evidence as to the relative ages of the more acid and the more basic portions of the Fundamental Complex is forthcoming, the latter are always seen to be the earlier.* In the banded rocks it is usually impossible to make out any difference of age between the darker and lighter portions; but occasionally, as in the part represented in Plate XIV., this may be done, and the evidence is then seen to be in accordance with the general law. The darker bands have in places been torn to shreds, which now lie in a matrix of more acid material.

The architectural features above described occur in those portions of the complex in which the rocks have affinities with igneous products. It becomes interesting, therefore, to enquire whether normal plutonic masses present phenomena in any way comparable to those above described.

Hornblende-biotite-granites or quartz-diorites, such as those of Criffel, usually contain basic inclusions, and are traversed by acid veins. The relative ages of corresponding petrographic types are, therefore, the same in the Lewisian Gneiss and in those masses of plutonic rock which most nearly resemble it in composition. But the architectural features are in many respects very different. Under these circumstances it is extremely interesting to note that on the southern margin of the Criffel mass there is a narrow zone in which the characteristic features of the Lewisian gneiss are reproduced.† Basic inclusions are here extremely common, and

* It must, however, be remembered that the later basic intrusions which clearly cut the gneissose banding in the central area have in some regions, as for example, south of Poolewe, been so modified by later movements that they may easily be mistaken for a part of the fundamental complex.

† See *Explanation to Sheet* 5, p. 24.

they have been drawn out into lenticles and bands by differential movement which has affected also the later acid veins.

Owing to the extreme petrographic diversity of the Lewisian Gneiss it is impossible to obtain a fair sample of the mass; but if this could be done it would probably be found that the average composition is that of an intermediate rock—not very different from the Criffel granite.

CHAPTER VI.

B.—ROCKS OF PRESUMABLY SEDIMENTARY ORIGIN IN THE LEWISIAN GNEISS.

MICA-SCHISTS, GRAPHITIC SCHISTS, QUARTZ-SCHISTS, CALCAREOUS ROCKS.*

The rocks of the Fundamental Complex, above described, have in most cases marked affinities with igneous products. Such rocks make up the greater portion of the area mapped as Lewisian Gneiss. Nevertheless we find included within that area, in certain districts, and especially in the neighbourhood of Gairloch and Loch Maree, some rocks of a very different character, which have equally decided affinities with sediments. These include mica-schists, graphitic schists, quartz-schists, siliceous granulites, limestones, dolomites, and cipolins.

I. *Mica-schists.*

Three distinct types of rock, as well as certain varieties more or less intermediate between these three types, are included under the general term of mica-schist. The three types may be defined as follows:—

(*a*) Fine-grained, dark-brownish, often platy schists.
(*b*) Silvery mica-schists, often containing large, idiomorphic garnets.
(*c*) Fine-grained, dark-gray granulitic biotite-schists, or biotite-granulites.

(*a*) A specimen from the road-side, ½ mile west of Loch Badna-Sgalaig, between Loch Maree and Loch Gairloch (3751), may be taken as an example of the first type. It is a dark brown, fine-grained, platy mica-schist. The flat surfaces of schistosity possess a silky lustre and show a fine parallel striping. The rock is essentially composed of brown mica, white mica, and quartz, with small grains of zircon, iron-ore, and garnet as somewhat rare accessories. The micas occur in thin plates uniformly scattered through the mass of the rock, not aggregated in planes. The individuals of quartz are irregular in outline and variable in size, the largest measuring about ·3 or ·4 mm. in diameter. Although often of fairly uniform dimensions in the different directions, a slight tendency to flattening in the direction of schistosity and

* By J. J. H. Teall.

elongation in the direction of striping may be observed. Undulose extinction, due to strain, is common.

In microscopic structure there is a marked contrast between the section at right angles to the schistosity and parallel to the striping, and that at right angles to the schistosity, and also at right angles to the striping. The former shows a perfect parallel structure, due to the arrangement of the mica-flakes; the latter shows the mica-flakes lying at all angles, and gives unmistakable evidence of minute puckering.

This rock has been analysed by Mr. Wilson with the following results:—

SiO_2 - - -	75·31
Al_2O_3 - - -	8·45
Fe_2O_3 - - -	2·84
FeO - - -	4·68
MnO - - -	·13
CaO - - -	1.27
MgO - - -	1·53
K_2O - - -	4·71
Na_2O - - -	·01
Ignition - - -	1·19
	100·12
Sp. Gr. - - -	2·73

The other rocks grouped under this head may all be described as dark brown biotite-schists. They vary a little in the sizes of the essential constituents, in the tint of the biotite, which is sometimes pale-brown and sometimes deep reddish-brown, and in the presence of accessory constituents. Felspar is often and may be always present. It is usually untwinned, water-clear, and may be easily mistaken for quartz.

One specimen of this type from Loch Maree (4273) deserves special mention as furnishing indisputable evidence that the rocks have been subjected to deformation since the period of crystallisation. This rock shows, under the microscope, the structure of a mylonite. Lenticles of felspar, and perhaps in some cases of quartz, lie in a matrix of mylonised quartz and biotite. The lines of biotite, composed of flakes which have been frayed and torn to shreds, wind round the lenticles of felspar, thus producing a most perfect type of fluxion-structure.

(*b*) As an illustration of the second type of mica-schist, a specimen (4322) from Meall Each, near Ben Slioch, Loch Maree, may be selected. This is a somewhat platy schist, with bright, silvery lustre on the surfaces of schistosity which are roughened by the projection of idiomorphic garnets. On a cross-fracture the planes of foliation are seen to be partly truncated by the garnets, and partly to wind round them. The matrix of the rock is composed almost entirely of a colourless or pale-green mica, a reddish-brown biotite, and epidote. Quartz and iron-ores are also present. The white mica occurs in thin plates often measuring more than 1 mm. in breadth. The plates lie, as a rule, with their flat surfaces in the plane of schistosity; but occasionally a plate may be seen to lie transversely without having suffered any distortion.

The reddish brown mica is irregular in outline and does not show any very definite orientation. The epidote exhibits a marked tendency to assume a prismatic form with ragged terminations. The individuals often measure over 1 mm. in length. The large garnets lie as porphyritic constituents in the matrix. They are bounded by sharp, well-defined, crystalline faces, and often contain iron-ore as inclusions.

A bulk analysis of this rock by Mr. J. Grant Wilson gave :—

SiO_2 - - -	46·11
Al_2O_3 - - -	28·25
Fe_2O_3 - - -	4·78
FeO - - -	6·51
MnO - - -	·53
CaO - - -	3·47
MgO - - -	3·09
K_2O - - -	6·01
Na_2O - - -	·26
Ignition - - -	1·18
	100·19
Sp. Gr. - - -	3·11

The other rocks referred to in this group differ as regards the relative proportions of the different minerals. Felspar is sometimes present in considerable quantity, and quartz is often more abundant than in the rock selected as a type.

(*c*) The third type of mica-schist is well represented by a specimen from a point about one mile W.N.W. of Lochan Fada Inlet, three miles north-east of Loch Maree (4414). The greater portion of this specimen shows the structure of a granulite rather than that of a schist. It possesses, however, schistose partings extremely rich in biotite. The principal constituents are a deeply-coloured biotite, quartz, alkali-felspar, and epidote. The biotite occurs as thick plates without any very strongly marked idiomorphism or definite orientation, the quartz and felspar as irregular grains and the epidote as ragged patches, the continuity of which is much interfered with by the other constituents. White mica and sphene are present as accessories.

Another specimen from the same locality (4413) is dark-brown in colour and fine-grained, with scattered plates of white mica. The constituents are granulitic quartz and alkali-felspar with biotite. The white mica occurs in thin plates which often lie across the planes of schistosity, and do not show any trace of deformation.

II. *Graphitic Schists.*

The graphitic schists are characterised by the presence of a variable amount of black carbonaceous matter which is disseminated through the rock, and occurs as inclusions in minerals such as biotite and hornblende. When the powder of the rock is treated with hydrochloric and hydrofluoric acids, the carbonaceous matter is obtained in a tolerably pure state, and is then seen to possess the properties of black lead. The examination of thin sections shows that the substance occurs as minute particles which may be either arranged in lines or aggregated together in opaque patches. Definite crystalline plates of graphite have not been observed.

The microscopic examination of the rock is attended with considerable difficulty in consequence of the opacity of the slides. Felspar is frequently recognisable as a constituent of a fine, micro-crystalline mosaic, and the larger individuals sometimes show albite-twinning. It is apparently andesine or some allied species. The carbonaceous matter is scattered through the rock in such a way as to show that the development of the mosaic has had little or no influence on its distribution. Colourless and brown micas occur in different specimens. They also contain inclusions of carbon, and the arrangement of these inclusions is similar to that occurring in the matrix of the rock, thus proving that the micas must have grown in situ after that arrangement had been brought about.

A specimen from Allt-na-Leth-Chreige (1⅓ mile east of Letterewe, Loch Maree) (4427), is a black, platy schist with radiating masses of actinolite. A cross-section of this specimen is seen to be traversed by wavy streaks of carbonaceous material separated by lighter streaks or folia of quartz and felspar. These folia sometimes wind round fragments which appear, under ordinary light, to be similar to the main mass of the rock, but which, under crossed nicols, polarise as individuals, and can be definitely identified as hornblende. It is clear that the actinolite was developed in an impure carbonaceous shale, in the same way as the tremolite described by Mr. Allport in a contact-rock from Botallack,* and that, when the deformation of the mass took place, those portions which were cemented by hornblende-substance offered greater resistance to the deforming stresses than those which were not so cemented. This actinolite-schist furnishes, therefore, indisputable evidence of the development of hornblende in a solid rock, and of the subsequent deformation of this rock by mechanical means.

A specimen from Allt Airidh na Eilein, one mile north-west of Letterewe, Loch Maree (4793), deserves special mention in this connection. It is almost entirely composed of hornblende and carbon. The substratum, so to speak, is a coarse-grained

* "Metamorphic Rocks surrounding the Land's End Granite." *Quart. Jour. Geol. Soc.*, xxxii., p. 410.

aggregate of allotriomorphic individuals of hornblende, and the black streaks pass through this aggregate without any reference to the optical orientation of the grains. In this rock there is no evidence of deformation since the hornblende was developed. The composition, apart from the carbonaceous matter, must have agreed very closely with that of hornblende; not exactly, however, for a few scattered idiomorphic garnets, a little quartz and felspar, and some biotite also occur.

The specimens, regarded as a whole, vary in colour according to the amount of carbon present; some are black, others lead coloured. The majority show a parallel structure which probably represents stratification more or less modified by subsequent mechanical movements.

Mr. J. Hort Player kindly made partial analysis of a specimen from Mill na Claise, one mile west of Loch Bad an Sgalaig. (4188).

Moisture - - - - - -	·8
Loss by ignition in reducing atmosphere	3·4
Further loss, probably all carbon -	19·6
	23·8

III. *Quartz-Schists.*

Highly siliceous rocks, which are usually granulitic in texture, and which probably represent the more arenaceous types of of sediment, are found in the same areas as the mica-schists and graphitic schists. Apart from one or two specimens, which consist almost entirely of quartz or of quartz and felspar, these rocks may be grouped under two heads—(*a*) quartz-hornblende rocks and (*b*) quartz-magnetite-rocks.

(*a*) The typical quartz-hornblende-rocks consist of a granulitic aggregate of quartz with which more or less green actinolitic hornblende is associated. They vary considerably as regards the relative amounts of the two chief minerals, some specimens consisting almost entirely of quartz, others containing the two minerals in nearly equal proportions. Variations from the type depend on the introduction of other minerals, such as chlorite and epidote, and on the extent to which the rocks have been modified by dynamic action. Some specimens are dark, others nearly white; but the dark varieties do not contain as much hornblende as might at first sight be supposed. The quartz, which is the principal constituent, is perfectly transparent, so that a small proportion of the dark hornblende, scattered through the colourless quartz, affects, in a marked manner, the general aspect of the rock. The dark varieties of quartz-hornblende rocks always show a peculiar resinous lustre which distinguishes them from the ordinary hornblende-schists of the district. As regards the origin of these peculiar rocks it is, perhaps, not desirable to speak with any great degree of confidence. It may, however, be pointed out that the association of quartz and hornblende, without felspar, is unknown in igneous products.

A compact, dark, platy rock with resinous lustre (4340) from the road $\frac{3}{4}$ of a mile S.S.W. of Meall Aundrary was analysed by Mr. Wilson. It is essentially composed of quartz, hornblende and epidote. The quartz gives undulose extinction, and has been partly mylonised,

SiO_2 - - -	71·55
Al_2O_3 - - -	5·73
Fe_2O_3 - - -	7·27
FeO - - -	3·68
MnO - - -	·19
CaO - - -	6·36
MgO - - -	1·88
K_2O - - -	·95
Na_2O - - -	·79
Ignition - -	1·54
	99·94
Sp. Gr. - - - -	2·84

(*b*) The quartz-magnetite rocks are usually granulitic or hälleflinta-like in texture. A specimen from Torr an Fhithich, near Smiorasair, $1\frac{1}{2}$ mile from head of Loch Maree (4664), may be taken as a type. It is a compact, banded rock. The bands appear dark and light on a weathered surface owing to a variation in the amount of magnetite present. They vary in width, and, in one part of the specimen, have been bent into S-shaped folds. A cut surface of the rock appears brown, owing to the partial oxidation of the magnetite. The constituents are quartz, magnetite, ferric oxide, and a mineral which forms slender prisms—probably sillimanite. The quartz breaks up under crossed nicols into an aggregate of a peculiar type. It is not composed of sharply defined grains which are independently orientated, as is the case with typical granulites; but of somewhat ill-defined grains which show a tendency to uniform orientation. As the nicols are rotated through 360° the quartz-aggregate shows four positions of maximum and four positions of minimum illumination. The orientation is by no means exact; nevertheless it is quite unmistakable, and differentiates the rock from a typical granulite. The magnetite forms compact streaks or lenticles, and rarely occurs as detached idiomorphic crystals. The compact masses occasionally show projecting portions bounded by crystalline faces. The rock, as a whole, exerts a marked influence on the magnetic needle. A partial analysis of this rock yielded the following result:—

Silica - - - -	90·3
Ferric oxide and alumina -	8·5
Loss on ignition - -	·02
	98·82

No lime could be found, and only a trace of magnesia. No importance must be attached to the relative proportions of silica and iron. It would be possible to select for analysis specimens of

Junction of one of the included fragments with the matrix shown in Plate X. 1200 yards S.E. of the top of Creag Mhor Thollie, two miles south of Poolewe, Ross-shire.

this group of rocks which would consist of almost pure quartz or pure magnetite.

Other specimens differ somewhat in the character of the quartz aggregate. In some (4320) this is typically granulitic, in others (3754) it contains large and extremely irregular individuals which sometimes abut against each other along sutural junctions, but are more frequently separated by a variable amount of micro-crystalline material. That the rocks have been subjected to dynamic action is proved not only by the folding seen in the type specimen, but also by the structure of many microscopic sections. Flaser of micro-crystalline quartz wind round phacoids of magnetite in the most striking manner, and thus produce the structure characteristic of differential flow.

It is interesting to compare the rocks of this and the preceding group with certain rocks found in the Penokee iron-bearing series described by Irving and Van Hise.* The rocks of this series include (1) cherty carbonates; (2) ferruginous slates and cherts; and (3) actinolitic and magnetitic slates. The quartz-hornblende rocks and the quartz-magnetite rocks from the Loch Maree area have decided affinities with the actinolitic and magnetitic slates of Van Hise. Both groups of rocks contain the same minerals and possess to a certain extent the same structures.

IV. *Calcareous Rocks.*

Calcareous rocks are represented by limestones, dolomites, and cipolins, that is, rocks mainly composed of carbonates but containing also various silicates. The specimens include compact white or cream-coloured dolomites, often veined with calcite, grey compact limestone, and white crystalline marble. Under the microscope the rocks are sometimes seen to consist of an aggregate of crystalline grains of approximately uniform size; more frequently, however, the individuals vary considerably in size, so that the rocks have a brecciated aspect. There is no doubt that they have, in many cases, been subjected to deformation since the development of crystallisation, and under conditions which admitted of the fracture of the individual crystalline grains.

In addition to the carbonates, the rocks of this group often contain one or more of the following minerals:—Quartz, mica, tremolite, green hornblende, garnet, felspar, and epidote.

Quartz, when present, is usually in the form of a very fine micro- or crypto-crystalline aggregate which is either intimately mixed with the carbonate or present as thin folia. When grains of considerable size are present they are usually separated from each other by a little micro-crystalline material, due apparently to the peripheral granulation of the larger individuals. In a few rare cases very large individuals may be seen, forming thin plates in the plane of foliation.

Mica is frequently present in well-developed plates which have often been puckered and distorted by interstitial movement. It

* *Monographs of U.S. Geological Survey*, vol. xix. (1892).

may be colourless, brown, or greenish brown. The darker-coloured varieties occur in bands. They possess a very small optic axial angle, whereas in the white mica the axial angle is considerable. Both green and colourless hornblendes are found, the latter sometimes occurring as conspicuous radiating masses of tremolite. Felspar has been observed only in one specimen (5478). It is a basic oligoclase or andesine, and occurs as irregular, twinned grains in association with quartz, a ferriferous carbonate, and rutile. Garnet, also, has been observed in one specimen (4795). It is brown in the hand-specimen, but practically colourless in thin section, and does not show the anomalous double refraction so frequently seen in the garnets found in limestones.

The rocks vary considerably in colour and structure. They may be white, grey, greenish-grey, or cream-coloured; compact or coarsely crystalline; schistose, banded or massive. The banding in a rock from Allt Airidh a' Char, one mile N.N.E. of Ardlair, Loch Maree (5480), is strongly suggestive of stratification. It is due to the concentration of silicates along certain definite layers.

The calcareous portion of a banded specimen from Allt Airidh a' Char (5480) was analysed by Mr. Wilson :—

Insol.	9·57
S_1O_2	·13
Al_2O_3	·16
Fe_2O_3	1·44
FeO	1·42
MnO	·36
CaO	34·25
MgO	11·75
CO_2	40·65
	99·73
Sp. Gr.	2·78

The insoluble portion consisted mainly of silica, which is recognisable in the microscopic section as microcrystalline quartz. The original rock was probably a cherty carbonate. It effervesces freely with cold, dilute hydrochloric acid, and the analysis shows that it has only been partially dolomitised.

Another specimen (5475) from a point east of Allt Coire nan Dearcag, one mile north of Ardlair, on the north side of Loch Maree, gave the following result. The rock is a white, saccharoid dolomite containing a few flakes of a nearly colourless mica :—

Insol.	1·35
S_1O_2	·06
Al_2O_3	·09
Fe_2O_2	·97
FeO	·45
MnO	·35
CaO	32·8
MgO	21·01
CO_2	42·55
	99·63

The foregoing descriptions show that the rocks of the Loch Maree and Gairloch area differ markedly in composition and structure from those which form the main mass of the Lewisian Gneiss. This difference is best explained by the assumption that they represent metamorphosed sediments, the mica-schists corresponding to argillaceous, the siliceous granulites to arenaceous, and the marbles and cipolins to calcareous deposits. It must not, however, be forgotten that some of the siliceous rocks may represent cherts.

In addition to the rocks above described, we find also chlorite-schists, cyanite-gneiss, and a peculiar rock which may be termed cummingtonite-garnet schist; but these are present only in small quantity. The chlorite-schists possess no feature of special interest, and, as they are unimportant so far as distribution is concerned, need not be further referred to.

Cyanite-gneisses occur near Carnmore Old House, four miles N.N.E. of Letterewe, Loch Maree (5115, 5116, and 5117). They are coarse-grained, quartzose biotite-gneisses. The cyanite is sometimes very conspicuous, forming crystals measuring an inch or more in length. The other constituents are quartz, felspar (oligoclase and orthoclase) and biotite. Two of the specimens above referred to are almost entirely free from felspar.

The cummingtonite-garnet schist is a remarkable rock occurring at a point about $\frac{5}{12}$ths of a mile south-west of the outlet of Loch Bad-na-Sgalaig, between Loch Maree and Gairloch (5125). The cummingtonite was at first mistaken for sillimanite, and the rock is referred to in the Annual Report of the Geological Survey for 1895 (p. 18) as a sillimanite-garnet-schist. It consists of numerous brown garnets about the size of small shot scattered through a light coloured, silky, fibrous matrix. A bulk analysis partly made in duplicate by Mr. J. Grant Wilson gave the following result, and at once disposed of the idea that the silky, fibrous mineral was sillimanite:—

S_iO_2	52·01	51·78
Al_2O_3	7·22	7·2
Cr_2O_3	·54	·54
Fe_2O_3	2·2	2·52
FeO	18·68	18·68
MnO	6·72	7·45
CaO	·88	·99
MgO	9·38	8·98
K_2O	·81	·81
Na_2O	·31	·31
Loss on ignition	1·33	1·33
	100·08	100·59
Sp. Gr.		3·38

Under the microscope the rock is seen to be essentially composed of garnet and cummingtonite. The garnet is pale reddish brown, and varies in size from 1 to 3 mm. The cummingtonite forms a fibrous aggregate in which the garnet is embedded. The fibres sometimes abut against the garnets and sometimes wind round their edges. More rarely they occur as inclusions in the garnet. They are colourless, and show cross jointing. The isolated fibres give extinctions varying from 0° to 20°. Quartz and iron-ores occur as unimportant accessories.

The two principal minerals were isolated by Dr. Pollard and analysed by Mr. Grant Wilson with the following results:—

	I.	II.
S_1O	37·45	54·56
T_1O_2	·25	—
Al_2O_3	20·08	5·02
Cr_2O_3	·34	—
Fe_2O_3	4·35	·82
FeO	15·05	16·12
MnO	19·61	4·89
CaO	1·86	·38
MgO	·30	14·99
K_2O	·57	·76
Na_2O	·26	·21
Loss on ignition	·22	1·67
CO_2	—	·63
	100·32	100·05
Sp. gr.	4·1	3·21

I.—Spessartite. II.—Cummingtonite

From a consideration of specific gravities Mr. Wilson concludes that the rock. consists of about one part of garnet to four of cummingtonite.

CHAPTER VII.

C.—PRE-TORRIDONIAN INTRUSIVE ROCKS ASSOCIATED WITH THE LEWISIAN GNEISS.*

ULTRA-BASIC DYKES; BASIC DYKES AND SILLS; MICROCLINE-MICA DYKES; BIOTITE-DIORITE DYKES; GRANITE AND GNEISSOSE GRANITE DYKES AND SILLS; PEGMATITES.

Dykes and sills of later date than the Fundamental Complex are extensively developed in certain regions. These belong to three periods—(1) pre-Torridonian; (2) post-Torridonian and pre-Tertiary; (3) Tertiary. The post-Torridonian intrusions are insignificant in amount. They include porphyrites and other rocks of the same age as the post-Cambrian intrusions of the Assynt district, and also Tertiary dolerites. These rocks will not be described in the present chapter.

The pre-Torridonian intrusions include ultra-basic rocks of the picrite type, dolerites (diabases), granites, pegmatites, and various schistose or massive rocks which have resulted from the modification of these types. These rocks will now be described.

I. ULTRA-BASIC DYKES.

A few dykes of ultra-basic composition occur in the area represented in Sheets 101 and 107. The least-altered rocks are dark in colour, massive in texture, and mainly composed of olivine and augite, together with a certain amount of reddish-brown biotite, magnetite, and a basic felspar. A specimen from a dyke occurring 1 mile N.N.E. of Little Assynt, near the outlet of Loch Assynt (3307, 8123), may be taken as a type. It is remarkable for the occurrence of conspicuous individuals of a green or yellowish-green pyroxene, often measuring ¼-inch across. At first sight this mineral appears to form porphyritic crystals in a dark, fine-grained matrix; but on closer examination it is seen that it occurs in irregular patches rather than as distinct idiomorphic crystals. This augite contains chromium.

Under the microscope the two chief constituents are seen to be olivine and augite. The olivine occurs in rounded grains and more or less idiomorphic crystals varying from about ·5 to 1 mm. in diameter. The actual olivine-substance is colourless or nearly so; but it frequently contains a large number of very minute inclusions which give a cloudy aspect to the mineral when viewed

* By J. J. H. Teall.

under low powers. In addition to these minute inclusions, there are also the usual anastomosing strings of magnetite. In the type-specimen there is no trace of serpentinisation, but wherever the olivine is in contact with felspar there is a narrow zone, about ·02mm. in width, of a pale green mineral. The nature of this mineral cannot be determined with absolute certainty, owing to the narrowness of the zone and the overlapping of the individuals, but from what is known of similar occurrences there can be little doubt that it is hornblende.

The augite is nearly colourless in thin section, showing only a faint greenish or brownish tint. When, as frequently happens, two individuals abut against each other, the boundary line is irregular; but when an individual is in contact with felspar, traces of idiomorphism may sometimes be seen. Twinning is rare. The structure is micro-poikilitic, in consequence of the presence of numerous inclusions of olivine.

The felspar is labradorite or bytownite, and frequently shows twinning on the albite and pericline plans. It is allotriomorphic with respect to olivine and augite, and therefore acts as interstitial matter with reference to the other constituents.

Biotite is present only as an accessory. It occurs as irregular plates which are frequently crowded with opaque inclusions. The colour, in the position of maximum absorption, is a deep reddish-brown. Magnetite is almost entirely confined to the olivine; but it occurs occasionally as independent idiomorphic crystals.

This rock evidently occupies a position intermediate between olivine-gabbro and peridotite. It contains more felspar than a typical picrite, but this difference seems scarcely sufficient to justify the introduction of a new term. The large amount of olivine sharply differentiates this rock from the non-olivine-bearing dolerites or diabases, of which the basic dykes are so largely composed. The following analysis was made by Mr. Grant Wilson. It agrees with those of typical picrites so far as magnesia is concerned, but contains larger amounts of silica and alumina:—

S_1O_2 - -	46·23
Al_2O_3 - -	6·3
Fe_2O_3 - -	4·3
FeO - -	7·07
MnO - -	·33
CaO - -	6·08
MgO - -	25·13
K_2O - -	·33
Na_2O - -	1·08
Loss on ignition -	3·78
	100·63
Sp. gr. - -	3·04

Another specimen gave sp. gr. 3·13. Chromium was found to be present in the pyroxene, but only in small quantity. It was not estimated in the bulk-analysis.

Picrite dykes of the above type occur on the south side of Loch Assynt and near Brackloch, about two miles on the road from Loch Inver to Inchnadamff. But the dyke at Brackloch (3310) is more altered. It differs principally in the fact that the place of the felspar is almost entirely taken by fibrous aggregates of a colourless or pale green fibrous hornblende. A distinct zonal arrangement of this hornblende with reference to the still comparatively fresh olivine may be seen, the axes of the fibres being arranged more or less at right angles to the surfaces of the adjacent olivines. Owing to this arrangement the intervening spaces, originally occupied by felspar, break up into fields bounded by lines due to the interference of fibres which have grown outwards from the neighbouring olivines. The narrow zones which surround the olivines, in the least-altered rocks, are still recognisable; a fact which proves that they correspond to an original zoning and do not simply represent the initial stages of the process by which the felspar substance has been replaced by secondary minerals. The olivine in this specimen shows the commencement of serpentinisation.

Another specimen (4466), also from Brackloch, shows a further increase in the amount of alteration, accompanied by the development of carbonates; while a third (2937) is composed entirely of secondary minerals, with the possible exception of some magnetite. This rock deserves a more detailed description. It is medium-grained, greenish-grey, and massive. The most conspicuous mineral, under the microscope, is a colourless hornblende, more or less idiomorphic in the prismatic zone, but always having ragged terminations. It is irregularly distributed in an aggregate of pilitic hornblende and chlorite. Here there is evidence of the conversion of a rock, originally composed of olivine, augite, felspar, and magnetite, into an aggregate of hornblende, chlorite, and magnetite. The original structure is not entirely lost in the process, for the forms of the olivines may occasionally be recognised in pseudomorphs of pilitic hornblende and chlorite. The fact that olivine has been replaced by pilitic hornblende and chlorite is probably due to interchange of material between that mineral and felspar.

A specimen from one of the dykes on the south side of Loch Assynt (3048) shows the more common type of alteration into serpentine, and it is worthy of note that in this case no felspar is recognisable. A somewhat similar rock (3947) in which the serpentinising process has been carried still further occurs as a dyke in the thrust gneiss on the south side of Sgonnan Mhor, 6½ miles south-east of Inchnadamff, Assynt (1-inch Sheet 102).

The comparatively unaltered rocks belong, with one or two doubtful exceptions, to the picrite group; but the altered rocks are often so completely changed, both in structure and composition, that it is impossible to speak confidently as to their original character. A specimen from a dyke at Loch-nan-Eun, one mile north-east of the bridge at Loch Inver (3960), is composed of grains of olivine in a matrix of chlorite and hornblende, with magnetite as an accessory. The chlorite is nearly colourless and shows only the faintest traces of pleochroism in greenish and brownish tints. Under crossed nicols it polarises very much as felspar, and its resemblance to that mineral is still further increased by the presence of lamellar twinning. A similar chlorite has been described by Patton* in a bronzite-tremolite-chlorite rock, associated with serpentine, near Marienbad in Bohemia.

The rocks above referred to are all massive, but the dykes to which they belong furnish examples of every gradation from massive rocks to the most perfect schists. A series taken from a dyke occurring on the sea-shore south ot Loch-na-h-Irinne, about 3½ miles north-west of Loch Inver (2938–2943), illustrates this passage. The northern edge of the dyke is little, if at all, foliated; but from about the centre to the extreme southern edge the alteration increases progressively.

The rocks are dark greenish-grey in colour. The massive variety (2938) is composed of hornblende, biotite (pale brown), chlorite, carbonates (which do not effervesce with dilute acid), and iron-ores. The hornblende occurs in fibrous aggregates, or as small prisms with ragged terminations, forming, with the other constituents, a confused crystalline aggregate in which only faint traces of the original igneous structure are preserved. The most perfect schist (2942) is composed of the same minerals, with the possible addition of talc. Under the microscope slight signs of puckering may be observed. Microscopically the rock is a fine-grained chlorite-schist. The other specimens belonging to the series show different stages in the development of schistosity which appear to have taken place after the alteration of the original rock.

A remarkable example of a schist formed from one of the ultra-basic dykes occurs in the Tombstone quarry, by the roadside near Clach-toll, about 4½ miles north-west of Loch Inver. It is a greenish, silvery schist containing numerous uniformly distributed knots of siderite. These knots measure over ⅛-in. in diameter, and behave, in relation to the main-mass of the rock, exactly in the same way as the lenticles of felspar in augen-gneiss, or as the garnets in many mica-schists. They consist of single crystalline individuals, notwithstanding their lenticular form. The interior portions are seen to be perfectly colourless in thin sections, but the margins are often stained brown, and the staining sometimes extends along cracks into the interior.

The main mass of the schist is composed of chlorite, talc (?), carbonate, a colourless, rhombic hornblende (anthophyllite or gedrite), and magnetite. The rhombic hornblende occurs in long, slender prisms which lie at different angles in the plane of schistosity and invariably give straight extinction.

The silvery lustre on the planes of schistosity suggests the presence of talc, and the microscopic section indicates the presence of a scaly mineral with high double-refraction. The hydrochloric

* *Min. u. petr. Mitth.*, 1888, p. 89.

Imperfect banded structure in Hornblende-Gneiss. **Creag a' Mhail, north side of Scourie Bay, Sutherlandshire.**

acid solution contains a large amount of iron and a considerable amount of magnesia, but only traces of lime. The carbonates present must, therefore, be carbonates of iron and magnesia, which are those one would natually expect to find in an altered ultra-basic rock.

II. BASIC DYKES AND SILLS.

Between Loch Laxford on the north and Enard Bay on the south the Lewisian gneiss is traversed by an extraordinary number of basic dykes which follow a general north-west and south-east direction. In many places the true dyke-like character of the intrusions is perfectly obvious. More or less vertical walls of black basic rock clearly cut across the gneissose banding (Plate XX.). But in other places, owing to movements after or during the injection of the dykes, the dyke-like character is lost, and the rock of the dykes becomes more or less incorporated with the earlier complex.

In the southern area between Loch Maree and the islands of Rona and Raasay, the basic bands rarely, if ever, show the normal dyke-like character, although evidences of intrusion may not unfrequently be found if carefully looked for. It is not improbable that some of these masses were intruded as sills, especially those which are associated with the supposed sedimentary rocks. The rocks of which the dykes are composed vary considerably in mineralogical composition and structure, but would doubtless exhibit, if analysed, much greater uniformity in chemical composition. Three marked types, easily recognisable in the field, occur to which the general terms dolerite (diabase), epidiorite (amphibolite), and hornblende-schist have been applied. The rocks of the first group are essentially composed of labradorite, pyroxene, and magnetite with normal igneous structure; the epidiorites are plagioclase-hornblende rocks, with or without a mineral of the epidote group, and often without normal igneous structure; the hornblende-schists may be briefly described as foliated epidiorites. All three types shade into each other and may be found in one and the same dyke. Transitions from massive epidiorite to foliated hornblende-schist may take place within the limits of a hand specimen or even a microscopic section.

The rocks to which the general term dolerite has been applied are found on microscopic examination to be more variable in composition than was at first sight supposed. They are dark, medium to moderately coarse-grained holocrystalline rocks belonging to the diabase and gabbro families of Rosenbusch. The Survey collection includes rocks to which the terms diabase, enstatite-diabase, hornblende-diabase, gabbro, hyperite and norite would be applied by that author.

The minerals entering into the composition of these rocks are olivine, enstatite, augite (including diallage), hornblende, biotite, labradorite, and iron-ores. Olivine is usually absent, but occurs in a few specimens. When present it possesses the same characters as those described in connection with the last group of rocks. It contains the same minute inclusions and the same anastomosing veins of magnetite.

Enstatite is more common, but is by no means invariably present. It usually shows a marked tendency to idiomorphism, occurring in prismatic crystals similar in form to those found in the enstatite-andesites. Cross-sections are eight-sided, and the four prismatic faces are less developed than the pinacoids. Longitudinal sections are often terminated by two faces meeting at an obtuse angle. The sections are often colourless, but pleochroism of the common type may sometimes be observed. The above characters are best seen in the rock from a dyke on the north side of Loch Assynt, about 4 miles west of Inchnadamff (2319).

The monoclinic augite is often nearly colourless in thin sections, like the enstatite; but it occasionally shows brown tints, especially at the margins of the grains. Idiomorphism is much less prominent than is the case with the enstatite, and although the typical ophitic structure, so characteristic of the Tertiary dolerites, has never been observed, lath-shaped sections of labradorite do occasionally penetrate individuals of augite, thus giving rise to what may be termed a sub-ophitic structure. In the majority of cases the augite is free from inclusions; but it occasionally contains minute dots and rods like those occurring in the other minerals, and more rarely brown plates, like those of the well known hypersthene of St. Paul. The distinction between augite and diallage is valueless for classificatory purposes, so far as these dykes are concerned.

Green compact hornblende is found not only in the epidiorites but also in the rocks with true igneous structure. It usually occurs on the margins of the augite, and may be either idiomorphic or allotriomorphic with respect to labradorite.

Biotite is usually present, but never in any quantity. It occurs as reddish-brown scales, often in association with iron-ores.

The plagioclase-felspar may occur as broad laths, as irregular grains, or as large individuals which behave as a matrix in which the other constituents are embedded. Interstitial labradorite is especially characteristic of the rocks rich in enstatite, and lath-shaped labradorite of those which contain only monoclinic pyroxene.

When the powder of a rock is placed in a diffusion column the felspar concentrates at a level corresponding to sp. gr. 2.69. This observation was made on two specimens, in one of which the mineral was allotriomorphic, and in the other idiomorphic with respect to the pyroxenes. It agrees with the optical determinations, and proves that the dominant felspar is labradorite; but, as zonal structure may occasionally be observed, there are doubtless slight deviations from the type. In some of the specimens the felspar appears cloudy under low powers in consequence of the presence of extremely minute dots and rods similar to those seen in the other minerals (Plate XLVII., Fig. 2). The presence of these inclusions in olivine, augite, and labradorite, but not in all three minerals in one and the same rock, points to the conclusion that they are original products of the magma. But if so, they must have existed only at special stages in the consolidation, and must have been liable to resorption during the later stages when they occur only in the earlier-formed minerals.

Two or three varieties of rock will now be briefly described. The most common type is represented by a specimen (8627) from the hill-slope above the lowest Chalda Loch, about 1½ mile north-east of Inchnadamff. It is a medium-grained, black, massive rock composed of more or less lath-shaped labradorite, nearly colourless augite, and a very small amount of magnetite or ilmenite. Compact green hornblende and biotite also occur, but only as accessories. Some of the pyroxene grains and the marginal portions of others show a kind of micrographic structure under crossed nicols, as if they were formed of an intergrowth of two minerals—possibly augite and enstatite. This rock is a dolerite or diabase. The structure is represented in Plate XLVII., Fig. 1. Closely allied rocks occur ¾-mile S.S.E. of Ben Dreavie, a hill 1¾ mile S.S.W. of Ben Stack, east of Ruadh na Moine, on the south shore of Loch Assynt, one mile north-west of Inchnadamff (3103), north of Creag-a-Mhhail, one mile north-west of Scourie, and doubtless at many other localities in the central area. This type frequently passes over into epidiorite and hornblende-schist. In some of the rocks above-mentioned the lath-shaped form of the felspar is less marked than in the rock selected as a type, and the augite takes on the characters of diallage. Such rocks may be called gabbros. They appear to be especially characteristic of the central portions of the broader dykes (2944).

Another type of rock is characterised by the presence of enstatite. A good example of this type occurs near Tomore Lodge on the north shore of Loch Assynt (3042, 3043, 3044). The rock from the centre of the dyke shows lustre-mottling (macro-poikilitic structure) due to irregular individuals of labradorite measuring half-an-inch or more across. Both enstatite and augite are colourless, except at the edges, where they are sometimes brown and pleochroic. The former is more abundant than the latter and markedly idiomorphic. In this specimen there is an entire absence of diabasic structure; but in another from the same dyke (3044), taken between the centre and the edge, the labradorite shows a distinct tendency to take on the lath-shaped form. The interstitial character of the labradorite in the rock from the centre of the dyke, coupled with the idiomorphism of the enstatite, differentiates this rock from the norites and hyperites, but the differences are scarcely sufficient to justify the introduction of a new term. It is therefore a basic hyperite; while the rock with lath-shaped labradorite may be termed enstatite-diabase. Both rocks contain iron-ores and a very small amount of green hornblende and biotite. This dyke shows a passage into epidiorite (3040).

Examples of hyperite or enstatite-diabase occur also on the west side of Loch-an-Ruighein (2318), about one mile north of Little Assynt.

The rocks above referred to are either free from olivine or contain only an occasional grain; but a specimen from the dyke already cited from the north side of Loch Assynt, about 4 miles west of Inchnadamff, contains this mineral in abundance (2319). It is essentially composed of olivine, enstatite, and interstitial labradorite. The olivine is precisely similar to that of the picrites, and contains the whole of the magnetite present in the rock. The enstatite is colourless and idiomorphic (Plate XLVIII., Fig. 1). The rock may be termed olivine-norite, but the structure is not that of a typical norite, owing to the interstitial character of the felspar. Its specific gravity is 3·16. The abundance of olivine links this rock with the picrites.

The rocks which remain to be described under this head all contain green hornblende. At the one end we meet with true igneous structure in which the hornblende appears to be original (hornblende-diabase and hornblende-gabbro); at the other end the rocks show no igneous structure and pyroxenes are entirely absent (epidiorites or amphibolites).

A dyke from Loch a' Chroisg, 4½ miles S.S.W. of Inchnadamff, Assynt, which will be subsequently referred to as illustrating passage-forms between diabase and epidiorite, furnishes a good example of hornblende-diabase (2745 and Plate XLVII., Fig. 2). This specimen is composed of lath-shaped plagioclase, augite, enstatite, ophitic green hornblende, and iron-ores. The hornblende is compact, and does not appear to have originated from the pyroxene. The labradorite is quite fresh, but the central portions of the individuals appear turbid in consequence of the presence of minute inclusions. A similar rock occurs at Con a' Chreag, Loch Glen Coul, 1¾ miles south-east of Kylesku (2759).

The epidiorites are essentially plagioclase-hornblende-rocks, but sometimes contain also a mineral of the epidote group, together with quartz, iron-ores, and granular sphene often zoning the iron-ore.

They may be roughly separated into two groups according to the presence or absence of the structure characteristic of the gabbros, diabases, and hyperites. In those of the first group (*a*) the lath-shaped or interstitial character of the felspar-sections is in most cases well marked, and the characteristic inclusions so common in the felspars of the diabases are often present. The hornblende is of two types. There is the compact green hornblende, similar to that of the hornblende-diabases, and also the fine-grained and sometimes fibrous aggregates which appear to eat into and finally destroy the original augite. Cores of augite may frequently be detected in the centres of these hornblende-aggregates. A little interstitial quartz is often present.

Examples of this type occur on the north side of Scourie Bay (2371), at Con a Chreag, Loch Glen Coul (2760), about half-way down the north side of Loch Assynt (2935), and half a mile north-west of the Falls of Kirkaig, Assynt (3907); doubtless, also, in many other localities.

The typical rocks of the second group (*b*) of epidiorites are devoid of igneous structure. They are essentially composed of plagioclase and hornblende, with which some quartz and a mineral of the epidote group are often associated. The felspar occurs as irregular grains or in large ophitic patches; sometimes as granulitic aggregates. It is in general more allied to albite than the felspar of the pyroxenic rocks. Not unfrequently it is crowded with minute prisms and grains of epidote, thus forming the typical saussurite of Cathrein. Under these circumstances it is either albite (2933) or some closely allied felspar. The hornblende may be either pale or dark green. It occurs as spongy aggregates enclosing rounded grains of quartz, as compact irregular individuals, and as aggregates with ragged outlines from which prisms often jut out into the surrounding felspar. Detached grains and prisms often occur as inclusions in the felspar.

Biotite and iron-ores zoned with colourless granular sphene are frequently present (Plate XLVIII., Fig. 2).

Epidiorites of this type are extremely common in the central area, and may be obtained from almost any of the basic dykes. The collection of the Geological Survey contains good examples from the roadside at Loch na Bruthaich, Strath Croy, 2½ miles north-east of the village of Stoer (3948, 3949); from Eas Dubh on the Ullapool River, 1⅝ miles north-east of Ullapool (3067, 3068); and from the north side of Loch Assynt, 5¼ miles north-west of Inchnadamff Church (3041, 3040).

The massive epidiorites frequently pass into foliated rocks. These may be either typical hornblende-schists or rocks intermediate between epidiorites and hornblende-schists, which may be termed foliated epidiorites. Hornblende and felspar are the principal constituents. Iron-ores and granular sphene are usually present; epidote and quartz are occasionally found.

The powder of one of the typical hornblende-schists from the broad dyke crossing Ben Stack, north of Achfarry (2727), was placed in a diffusion column. The hornblende concentrated at a level corresponding to a specific gravity of 3·19—3·2; the felspar at a level corresponding to 2·69—2·7. The felspar of this rock, like that of the dolerites, is, therefore, labradorite; but its mode of occurrence is entirely different. It is present in the form of untwinned, often water-clear grains resembling quartz. In those rocks which contain epidote the felspar is albite or some closely allied variety.

Amongst the accessory constituents of the foliated rocks iron-ores and sphene deserve special mention. Where both are present the sphene takes the form of colourless granular aggregates in the centres of which one or more grains of iron-ore may be observed. Sometimes the iron-ore predominates, and the sphene merely forms a narrow zone; at other times the sphene predominates, and only one or two specks of iron-ore can be recognised. The deforming stresses by which the foliation has been produced have exercised considerable influence on the aggregates of sphene and iron-ore. They are sometimes in the form of thick lenticles; at other times they have been so dragged out as to be represented only by trains of small granules.

The distribution of hornblende and felspar in the rocks is worthy of special note. In many cases the minerals are not uniformly scattered through the rocks. Lenticular aggregates of granulitic felspar, or of felspar and epidote, alternate with others of hornblende. This is no doubt due to the coarse-grained character of the original rock. Aggregates have taken the place of large individuals; but the grains, formed at the expense of a large individual, have held together, so that the structure of the original rock has affected that of the schist, although the outlines of the folia are quite distinct from those of the original minerals. This peculiarity in the distribution of the two principal constituents is especially marked in those rocks which occupy an intermediate position between the massive epidiorites and the typical hornblende-schists. In the latter rocks it is not recognisable.

A specimen from the Ben Stack dyke, already referred to, may be selected as a type of the more perfect schists. It is a dark, medium-grained rock bounded by two more or less flat surfaces which correspond to the principal planes of schistosity. It shows a marked linear foliation. Three sections have been prepared from this specimen; one parallel to the principal planes of schistosity, another at right angles to these planes and parallel to the direction of stretching, and a third at right angles to this direction. A comparison of these sections shows that although the hornblende rarely exhibits traces of idiomorphism the individuals are more or less elongated in the direction of their vertical axes, and roughly arranged with their longest diameters parallel to the direction of stretching. The preparation at right angles to the direction of stretching abounds in sections which show the characteristic cleavages meeting at angles of 124°, whereas such sections are rare in the other two preparations. The colour scheme for the hornblende is X greenish yellow, Y green, Z green with a tinge of blue.

The felspar (labradorite) in this rock occurs in the form of untwinned grains, usually of equal dimensions in the different directions. It is partly water-clear and partly turbid in consequence of the development of minute overlapping scales of a micaceous mineral. Iron-ores and sphene occur as accessories.

A specimen from the dyke ¼ mile north-west of Loch a' Chroisg, 4½ miles S.S.W. of Inchnadamff, Assynt (2747, Plate XLVIII., Fig. 2), may be taken as a type of one of the less perfect schists (schistose epidiorite or amphibolite). It is a medium-grained rock, with a trace of linear foliation, composed of granulitic felspar, a mineral of the epidote-zoisite group, pale-green hornblende and granular sphene. The figure is taken from a section at right angles to the direction of linear foliation, so that the parallel structure is not strongly marked.

The principal types of rock occurring in the basic dykes have now been described at sufficient length, and it remains only to give some account of the mode of association of the different types. The transition from dolerite (diabase) to epidiorite and hornblende-schist was first observed in the case of the dykes occurring on the north side of Scourie Bay and running south-eastwards to Loch a' Bhaid Daraich.* They may be picked up again on the south side of the loch and followed for a considerable distance towards the south-east.

The least-altered rock is a typical diabase with sub-ophitic structure composed of labradorite, augite, titaniferous magnetic iron-ore, apatite, and some secondary products including hornblende (scarce), chloritic minerals, and quartz. At the other extreme is a typical hornblende-schist essentially composed of hornblende, felspar, iron-ore, sphene, and apatite. The two most extreme types were analysed with the following results:—

	I.	II.
S_1O_2	47·45	49·78
TiO_2	1·47	2·22
Al_2O_3	14·83	13·13
Fe_2O_3	2·47	4·35
FeO	14·71	11·71
MnO	—	·27
CaO	8·87	8·92
MgO	5·00	5·40
K_2O	·99	1·05
Na_2O	2·97	2·39
CO_2	·36	·10
H_2O	1·00	1·14
	100·12	100·46

I.—Diabase from dyke north side of Scourie Bay. P_2O_5 and S (in FeS_2) were not estimated. The P_2O_5 is therefore reckoned with the Al_2O_3. Three specific gravity determinations made on different samples gave 3·106, 3·105, and 3·086.

II.—Hornblende-schist from the same dyke. The specific gravities of two specimens were found to be 3·111 and 3·122. Both analyses by Teall.

The two analyses show a very close general agreement. No general conclusions can be drawn from the slight differences which exist.

Between the two extreme types of rock, occurring in one and the same dyke, many intermediate varieties may be observed. The replacement of the pyroxene by hornblende can be followed stage by stage, and as it becomes more and more pronounced the typical igneous structure is lost. The change first affects the peripheral portions of the pyroxene-grains and works its way inwards until no trace of the original mineral remains. The labradorite loses its lath-shaped character and takes the form of aggregates of irregular grains which are, in many cases, entirely destitute of twin lamellation. In this particular dyke the development of epidote or zoisite has not been observed, so that the felspar of the epidiorite, like that of the diabase, is labradorite. Some quartz has made its appearance in connection with the amphibolitisation of the pyroxene.

* "The metamorphosis of Dolerite into Hornblende-schist," by J. J. H. Teall, *Quart. Jour. Geol. Soc.*, 1885, pp. 133-145. See also *British Petrography*, Plates xix and xx.

At Creag a' Mhail, the promontory on the north side of Scourie Bay, and at the small bay about $\frac{1}{4}$ mile to the east of this point, both gneiss and dyke are traversed by narrow zones of secondary disturbance (see Sheet 107). At both these localities the passage from massive epidiorite to hornblende-schist is well displayed.

The dyke which runs along the north shore of Loch Assynt $\frac{3}{4}$ths of a mile E.S.E. of Tomore and $5\frac{1}{4}$ miles north-west of Inchnadamff Church has already been referred to. A series of specimens (3040–3045) has been collected from this dyke. The centre of the mass is a basic hyperite with interstitial labradorite; nearer the margin it becomes an enstatite-diabase with lath-shaped labradorite. Two other specimens (3040, 3041), probably from the central portions, are typical epidiorites or amphibolites, with saussuritic aggregates of epidote and a water-clear felspar belonging to the albite-oligoclase series. None of these specimens is foliated. This dyke is interesting as proving that the rocks with enstatite furnish epidiorites of the same type as those which arise from the alteration of the diabases.

Another series of specimens (2741–2750) was collected from a dyke $\frac{1}{4}$ mile north-west of Loch a' Chroisg, Assynt. The least-altered rocks (2742–2745) are hornblende-diabases. The other specimens are either massive epidiorites or foliated rocks of the type intermediate between epidiorites and hornblende-schist. There is in this dyke a marked difference in the coarseness of the grain between the central and marginal portions; but both the coarse and the fine-grained varieties have been converted into epidiorites. Apart from variations in the grain and the frequent changes from diabase to epidiorite the dykes are, as a rule, fairly homogeneous in composition. There are no marked differences depending on variations in the relative proportions of the ferro-magnesian and felspathic constituents. The central portions of this dyke do, however, show a want of homogeneity similar to that so frequently seen in the rocks of the fundamental complex, but on a much smaller scale. This is illustrated by one of the epidiorites in the above series (2746) in which irregular patches of black rock shade into others of a lighter colour, much richer in saussurite.

Acid segregations such as are occasionally seen in large masses of dolerite (*e.g.*, Stirling Castle Rock) appear to be extremely rare. One such case has, however, been observed by Mr. Peach. It occurs in a broad dyke about $\frac{1}{2}$ mile north-west of the Falls of Kirkaig, Assynt (3905–3908). The least altered rock is an enstatite-diabase (3908). The acid masses which occur in the centre of the dyke are coarse-grained aggregates of alkali-felspar, quartz, biotite, hornblende, and epidote.

So far, reference has been made only to the basic dykes of the central area, where the dyke-like character of the intrusion is often obvious, and where pyroxenic rocks with true igneous structures are not uncommon. In the southern area, basic igneous rocks are equally abundant, and many of these are certainly of later date than the fundamental complex; but the original character of the intrusion is often obscure: pyroxenes of the types found in the

Felspathic Gneiss with streaks and lenticles of basic (hornblendic) rock. Cliff face about 20 feet high.

central area have not been recognised, and true igneous structures are rare.

The massive rocks are amphibolites (epidiorites), and the foliated rocks are either hornblendic or actinolitic schists.

Broad bands of basic igneous rock are associated with the supposed sedimentary beds both on the north-east and south-west sides of Loch Maree (Sheets 91 and 92). These include massive epidote-amphibolites or epidiorites similar to those occurring in the dykes of the central area (3746), schistose varieties of the same rock (4995, 5491), hornblende-biotite schists (4786, 5489, 5487), fine-grained platy actinolite-schists (4996, 3746), and chlorite-schist (3747).

The broad belt of hornblende-schist about two miles north of Letterewe, Loch Maree, contains bands and lenticles of saussurite, composed of a mineral of the epidote-zoisite group and a turbid substance representing felspar (4423). The centre of one of these lenticles contains numerous crystals of blue tourmaline (6341). Tourmaline is a rare mineral in the Lewisian gneiss, and its occurrence in this rock is therefore of exceptional interest. Mr. Clough observed it also in pegmatite veins penetrating the hornblende-schist, and in one case it was found to be associated with quartz and axinite. This district appears to have been slightly affected by boracic acid exhalations similar to those which have so profoundly modified the rocks in certain parts of Cornwall.

In addition to the broad sill-like intrusions above referred to, there are also innumerable smaller bands associated with the true archæan gneisses. In the descriptions of the field-relations of these rocks it has been proved that they represent masses of basic igneous rock intruded into the fundamental complex, and that some of them exhibit dyke-like relations to the surrounding rocks. The majority are hornblende-schists, but they include also massive epidiorite, some of which show traces of felspar-phenocrysts (3744, 4193).

Near the centre of the district, south of Poolewe, in which Mr. Clough has proved the existence of a kind of anticlinal structure in the arrangement of the dyke-like masses, the hornblende-schist is linearly foliated, parallel with the pitch of the folds. This is well seen in a specimen from a point ⅝-mile north of Meall an Spardain (4434). The rock is essentially composed of green hornblende and a somewhat basic oligoclase. Quartz and a few grains of colourless sphene are also present. Two sections have been prepared; one parallel to the direction of foliation, the other transverse (Plate XLIX., Figs. 1 and 2). A comparison of the two shows that the individuals of hornblende, though irregular in outline, are arranged with their vertical axes approximately parallel with the direction of foliation, and consequently with the pitch of the folds in the district. The grains of oligoclase are irregular in outline and of approximately equal dimensions in the different directions.

The rock has not been subjected to mechanical deformation since the formation of the existing minerals. There are no signs of cataclastic action. These facts prove that the rock was either intruded during movement and consolidated in its present form, or that a previously formed rock was entirely recrystallised under the influence of the stresses which produced the "rodded" or "mullion-structure" of the district.

III. MICROCLINE-MICA DYKES.

In addition to the ultra-basic and basic dykes there are a few others of peculiar composition. A specimen from Creag Tombaca, Glen Dhu, 1½ mile E.S.E. of Kylesku (2734), may be selected as a type of a group having affinities with mica-traps. It is a massive purplish rock. The rough surface shows large, irregular cleavage planes of felspar, the lustre of which is interrupted by inclusions of biotite. The constituents are microcline, biotite, hornblende, calcite, quartz, sphene, apatite, and iron-ores.

Microcline is abundant, and occurs in irregular patches which give uniform extinction over large areas. It often appears cloudy under a low power in consequence of the presence of minute inclusions, amongst which scales of hematite may be recognised. Biotite occurs in very irregular plates, and contains numerous indeterminable inclusions. The hornblende, which is rare, is pale green in colour and idiomorphic in the prismatic zone. Calcite occurs in irregular grains. Apatite is abundant, and occurs either as thick hexagonal prisms or as fairly large grains which are frequently arranged in groups. Sphene is present in the granular form. Iron-ores are represented by the inclusions of hematite in the felspar and by a few opaque grains. Both in structure and composition this rock has affinities with the mica-traps.

Another specimen (3242) from a point half a mile north-east of Kyle Strome, near Kylesku, while agreeing in a general way with the one just described, presents some interesting points of difference. It is slightly schistose, and most of the felspar occurs in the form of untwinned grains in association with quartz. A few large individuals, often crowded with small scales of hematite, are present, and these show microcline-structure. Iron-ores in the form of irregular opaque patches are more abundant in this rock than in the one above described, and numerous green grains, which are either pyroxene or hornblende, are also present.

Two other specimens, one from Maldie, 1½ mile east of Kylesku (3863), and another from a point two-thirds of a mile E.S.E. of Unapool (2732), belong to this group, although the characters are not so well preserved as in the specimens above referred to.

Another specimen from Creag Tombaca (2733) is a fine-grained, dark, purplish schist composed of alkali-felspar, quartz, biotite, calcite, apatite, and sphene. The micro-structure is that of a typical crystalline-schist.

From the foregoing descriptions it follows that the massive rocks of this group are related in composition and structure to minettes, from which they differ mainly in containing microcline instead of orthoclase. Like most of the other archæan dykes found in the Lewisian Gneiss they are liable to pass over into crystalline-schists.

IV. BIOTITE-DIORITE DYKES.

A remarkable variety of biotite-diorite occurs at Allt-a-Mhullin, two miles S.S.W. of Loch Inver (3959). The rock is black, and shows lustre-mottling or macro-poikilitic structure in a most marked manner. The mineral which forms the substratum of the rock is a glassy plagioclase belonging to the oligoclase-andesine series (sp. gr. 2·65–2·66). Cleavage faces of this mineral often measure an inch or more across. The individuals are irregular in outline, and interlock with each other in such a way that if the other constituents could be removed, a spongy mass of felspar would remain possessing the form of the original specimen. Under the microscope the felspar is seen to be quite fresh, though often crowded with extremely minute inclusions. The other minerals are hornblende, biotite, iron-ores, and apatite.

Hornblende appears in two forms—brown and green. The brown variety occurs in crystals and irregular patches, often rendered nearly opaque by inclusions of iron-ore. It is deeply coloured and strongly pleochroic. The green variety forms either compact grains or fibrous aggregates. It is probably, in part at least, a secondary mineral after pyroxene. Biotite occurs in large ragged plates. The specific gravity of the rock is 3·05.

Another variety of biotite-diorite forms a dyke at Loch an Ruighein, north of Little Assynt (3958). The most striking feature of this rock is the occurrence of large blade-like crystals of a glassy felspar (oligoclase-andesine), which often show fine striation on the basal plane and also twinning on the Carlsbad plan. On the fractured surface these blades sometimes measure $1\frac{1}{2}$ in. in length by $\frac{1}{8}$th in. in breadth. They are not bounded by sharp outlines against the matrix, and cannot, therefore, be said to form porphyritic constituents in the ordinary sense of the term.

Under the microscope the large felspars are seen to be crowded with minute inclusions, the majority of which are colourless grains and prisms, too small for precise determination. The ground-mass is a crystalline granular aggregate of quartz, plagioclase, biotite, hornblende, calcite, epidote, and magnetite. Hornblende is scarce; biotite, in the form of small scales, is abundant. The specific gravity of the rock is 2·87.

V. GRANITE AND GNEISSOSE GRANITE DYKES AND SILLS.

Sills and dykes of granite and gneissose granite are extremely common in the neighbourhood of Laxford Bridge, and similar rocks occur in other areas of the Lewisian Gneiss. The sills are intimately connected with coarse-grained microcline-pegmatites which are often clearly intrusive in the rocks of the Fundamental Complex, and probably represent another facies of the same magma.

The specimens of granite and gneissose granite are, with one or two exceptions, medium-grained pink rocks, in which the parallel structure is due simply to the orientation of the constituents, especially the biotite, and not to a variation in the relative proportions of the different constituents in different layers. The intrusive magma was homogeneous. In this respect there is a marked contrast between the later intrusions and the Fundamental Complex, although some of the broader basic dykes do show signs of incipient differentiation. Cataclastic structures are usually absent, and the ordinary parallel structure is certainly not due to deformation since the constituents assumed their present forms.

The dominant minerals are oligoclase, microcline, and quartz. Biotite is the more common ferro-magnesian constituent; but hornblende has been observed in one or two cases. The rocks are thoroughly acid in composition (sp. gr. 2·61–2·63), and the ferromagnesian constituents are never present in any large proportion. Muscovite is not uncommon, but it occurs rather as an accessory constituent. The other accessories are epidote, orthite, sphene, iron-ores, apatite and zircon.

The three principal constituents all occur in irregular grains. The felspars sometimes contain rounded inclusions of quartz, but this is by no means a marked feature of the rocks. In one or two cases vermicular pegmatite was observed. Oligoclase has been more often affected by alteration than microcline, which is always perfectly fresh. Biotite occurs in small isolated plates, but is not, at any rate as a rule, idiomorphic in the prismatic zone. Of the other minerals, epidote is the only one that calls for any special reference. It occurs in irregular grains which frequently contain a core of deep brown orthite. Its relations to the other minerals do not suggest a secondary origin.

VI. PEGMATITES.

Pegmatites are extremely common in many portions of the Lewisian Gneiss, and their intrusive character is often clearly shown. In the neighbourhood of Laxford they are intimately associated with granites and granitic gneisses, into which they occasionally pass by imperceptible gradations.

The dominant type of pegmatite is an extremely coarse-grained rock, mainly composed of pink microcline and quartz, often intergrown so as to produce the well-known graphic granite. A white plagioclase, which may be either albite or an acid oligoclase, is also present, though, as a rule, in small quantity, and large plates of biotite (haughtonite) are occasionally found. The plagioclase may occur as independent crystals of considerable size, as a zone more or less enveloping microcline, or as perthitic and microperthitic intergrowths with microcline.

Individuals of microcline measuring several inches across are very common, and these frequently show two modes of intergrowth with plagioclase, both of which are well represented in a specimen taken from a point about 1½ miles north of Loch Stack (6290). In a section parallel to the brachy-pinacoid the plagioclase can be easily distinguished from the microcline by its stronger double-refraction. It extinguishes uniformly over the whole area of the section at an angle of about 19° in the positive direction as referred to the trace of the basal cleavage, and shows, with convergent polarised light, the oblique emergence of a positive bisectrix. These facts prove that the felspar in question is albite and that the two felspars are intergrown so that their brachy-pinacoids are, at least, approximately parallel. The albite occurs in narrow, irregular and often branching veins which show a rude kind of parallelism over the whole of the section. The angles which these veins make with the trace of the basal cleavage vary from 50° to 70°, so that there is here no regular succession of lamellæ parallel to the macro-pinacoid of the microcline. It is as if a number of more or less parallel cracks had been formed and the open spaces filled in with definitely orientated albite substance.

In addition to the phenomenon above described, there is also another and more or less distinct mode of intergrowth on a much smaller scale. When viewed with a low power the brachy-pinacoidal section presents a fibrous appearance which, when a higher power is used, is seen to be due to the occurrence of parallel rods or plates of a colourless mineral agreeing with albite in refractive index and direction of extinction.

The parallelism of these rods or plates, which are doubtless formed of albite, is much more marked than that of the broader veins, and their direction with reference to the trace of the basal cleavage can, therefore, be determined with considerable accuracy.

The angle is about 73°, with a possible error of about 1°. In the chapter on crypto-perthite, in the monograph on the minerals of the pegmatite-veins of southern Norway,* Prof. Brögger describes a somewhat similar intergrowth in which the striation on the M-face (010) makes an angle of 72° with the trace of the basal cleavage. He concludes that the soda-orthoclase, which agrees with this felspar in composition, is a sub-microscopic intergrowth of such a character that lamellæ of albite are arranged parallel to a steep ortho-dome ($\bar{8}01$). This would give a striation making an angle of 72° 2½′ with the trace of the basal cleavage, if the intergrowth were coarse enough to make itself recognisable under the microscope.

In a section of the above felspar taken parallel to the basal plane the cross-hatching of the microcline is well seen, while the albite of the veins shows only the normal lamellar twinning of plagioclase. The veins vary considerably in width and sometimes in direction, but their general course is at right angles to the trace of the brachy-pinacoid. The inclusions which produce the fine striation in the other section are here seen end on. They appear for the most part as oval dots; but occasionally, owing to the coalescence of several dots, a rod-like form is produced.

The minute inclusions are not distributed uniformly through the section, and where they are most abundant the broad veins are least conspicuous. Prof. Brögger has suggested that the finer inter-

* "Die Mineralien der Syenit-pegmatit-gänge der Südnorwegischen Augit und Nephelinsyenite." *Zeit. f. Krys*, Vol. XVI., Leipzig, 1890.

growths with orthoclase, parallel to the steep macro- or orthodome, are original structures, and that the coarser perthitic intergrowths which are often parallel to the macro- or ortho-pinacoid have been formed by secondary processes at the expense of the finer intergrowths. The phenomena seen in the above felspar from Scotland are undoubtedly similar to those described by Prof. Brögger, and his theory may apply to them.

Combining the results of the observations made on the two sections, we see that the fine micro-perthitic structure is due to the occurrence of extremely minute rods or plates of albite which lie in a plane corresponding very closely with the steep orthodome of orthoclase ($\bar{8}01$), and that the coarser perthitic structure is due to veins or irregular lamellæ which show a tendency to follow more closely a direction corresponding to the macro-pinacoid. The perthitic lamellæ are, however, very irregular, and so frequently give off branches at different angles that the crystallographic relations of the two felspars are of a very vague and indefinite character.

Another mode of association of the felspars is represented by a specimen from a point about $\frac{1}{4}$ mile E.N.E. of Badcall Storehouse, Loch Laxford. In this case a crust of plagioclase from $\frac{1}{8}$th to $\frac{1}{4}$ inch in thickness surrounds a crystal of microcline. Flakes of the plagioclase parallel to the brachy-pinacoid give extinctions of from 5° to 7° in the positive direction. The mineral is, therefore, oligoclase. The section (6326) which is approximately parallel to the basal plane of the microcline shows also intergrowths of plagioclase similar to those already described.

Mr. Clough found a small quantity of Amazon-stone in a pegmatite of the ordinary type, occurring near Badnabay, one mile west from Laxford Bridge. It is composed of alternating lamellæ of green microcline and white albite, the former measuring about 1·5 and the latter about ·4 mm. in thickness. The boundaries of the albite lamellæ are not so irregular as in the specimen of pink microcline above described. They correspond roughly with the macro-pinacoid of the microcline.

Biotite-pegmatites with pink microcline are by far the most common, and when the term pegmatite occurs in the description of the geology of the north-west of Scotland these rocks are almost always referred to. Biotite, however, is often absent. A few coarse-grained pegmatites are found in which albite or an acid oligoclase is the only felspar present. Good examples of these occur in some lines of movement in the Laxford area (6297, 6293, and 6298), where biotite is associated with the plagioclase. More or less crushed pegmatites, essentially composed of albite and muscovite (6328), occur at a point about $\frac{5}{8}$ mile south of Carnmore old house, four miles N.N.E., Letterewe, Loch Maree.

Microcline-pegmatites are abundant in certain parts of the northern and southern areas, but they are rare in the district occupied by the pyroxene-gneisses. They are usually massive; but very fine examples of foliated pegmatites in which the large individuals of microcline form "eyes" occur near Shieldaig on the south side of Loch Torridon (see Plate IX.)

CHAPTER VIII.

DESCRIPTIONS OF THE SEVERAL DISTRICTS OF THE LEWISIAN GNEISS.

CAPE WRATH TO LOCH LAXFORD.*

Character of Surface.—This district extends eastwards from Cape Wrath to the mouth of Loch Erribol, and is bounded on the landward side by a line drawn from the head of that sea-loch south-west to Loch-na-Tuaidh, and thence nearly due west to the river Laxford at a point about two miles above its mouth. The Lewisian Gneiss occupies slightly more than half of this area, the rest being mainly covered by the Torridon Sandstone. In the south the gneiss forms the promontory between Lochs Inchard and Laxford, and extends eastwards for a distance of 8 to 10 miles to the western slopes of Arkle and Fionne-Bheinn. North of Loch Inchard the gneiss appears in approximately parallel belts of irregular outline, which stretch from south-west to north-east, and are separated from one another by outcrops of Cambrian and Torridonian strata of varying breadth. The boundaries of these belts are to a large extent determined by a system of parallel faults which are described in the section dealing with the Torridonian rocks of this area. In the dreary region known as the Parph, between Cape Wrath and the Kyle of Durness, the tracts of gneiss are comparatively featureless, seeing that they are covered with extensive flat peat-mosses. It is only along the magnificent cliff sections on either side of the Cape, and on the western shore of the Kyle, that the relations of the rocks in this district can be satisfactorily observed.

West of the Durness limestone basin, and especially in the intensely glaciated region around Rispond, the gneiss presents a series of smooth, bare, mammillated surfaces that rise gradually from the shore of Loch Erribol to the summit of the rocky hill of Ceanna-beinn, a height of 1157 feet above sea-level. From this point the elevation of the gneiss increases gradually to the south-west, the older rocks rising to heights of 2000 to 2300 feet on the slopes of Spionnaidh and Crann Stacach, and passing beneath the Cambrian quartzite that caps the extreme summits of the hills that rise above the wild valley of the Dionard river. On the west side of this deep and rugged glen the gneiss forms the flanks and northern spurs of Fionne-bheinn; and on Ceann Garbh, the most northerly peak

* This district is contained in Sheets 107, 108, 113, and 114 of the Geological Survey Map of Scotland on the scale of one-inch to a mile ($\frac{1}{63360}$). The present chapter has been written by B. N. Peach, J. Horne, C. T. Clough, and L. W. Hinxman.

of that mountain, reaches a height of 2952 feet. This is the greatest elevation attained by unmoved Lewisian gneiss in Britain.

The country immediately south and south-east of Loch Inchard is known as the Ceathramh Garbh (pron. Kerroo Garrav), or "rough quarter," from its peculiarly rugged configuration. The observer who views this district from a distant elevation sees spread beneath him a billowy expanse of bare grey rock (see Plate I. for comparison), the crests of the ridges approaching more or less to a common level which is found to range from 400 to 600 feet in the south-east portion of the area, and from 300 to 450 feet in that to the north-west. The general impression thus conveyed is that of a plain of marine denudation, sloping gently towards the west. The whole district is cut up by innumerable valleys and craggy features running in divers directions, and not infrequently crossing the present watersheds. Many of the valleys and rocky features are almost straight, and mark lines of fault or crush. The majority of them run north-east and south-west; but a good many have a north-west and south-east direction, while a few run nearly due north and south.

As examples of the north-east-south-west series, reference may be made to those which pass through Loch Sgeir a' Chadha and Loch na Claise Inchairich, several of which are exposed on the north-west coast of Loch Laxford, and are there accompanied with thin dykes of diabase; also to those which pass through or near the eastern part of Loch Crocach, two miles west of Rhiconich, one of which, on the coast rather more than ¼ mile east of Ardmore, is as much as 5 yards wide.

The most prominent of the north-west-south-east features is the valley which runs so straight between Loch Inchard and the north side of Loch Stack, and which is occupied for a great part of its length by a series of long, narrow lakes. A line of crush probably runs near the valley bottom for most of its course, and passes in a north-westerly direction along the straight south-western side of the upper part of Loch Inchard. This southern area is remarkable for the multitude of small lochs of the most diverse shapes that are dotted over the surface. Besides those shown on the one-inch map several others are so hidden away among the rock-knolls as to have escaped the notice of the Ordnance Surveyors. Many of these lochans are undoubtedly rock-basins, and the gneiss can be traced uninterruptedly round them. They have, however, no general direction, and often wind about in a most complicated manner. Their long axes seem to be independent of the direction of the ice movement, and in a good many cases, as, for instance, Loch na Claise Inchairich, Loch na Fiacail, and Loch Crocach, lie along lines of crush or fault. The few larger lochs that occur in the gneiss areas of the north appear either to occupy hollows in the drift, or to be partially enclosed by accumulations of superficial deposits. The south-western coast-line is also deeply indented by branching sea-lochs, whose shores and islets afford excellent sections of the Lewisian rocks.

Along the western coast the Lewisian rocks have been laid bare

Bands and fragments of foliated basic material in more acid gneiss, near Loch a Bhaid Daraich, Scourie, Sutherlandshire.

in a series of lofty precipices, of which those at Cape Wrath are particularly striking (Plate V.).

Much of the gneiss in the northern district is covered with peat and drift, but in the region south of Loch Inchard a great part of the ground is bare of drift and even of vegetation, though many of the stream-courses are choked with drift boulders. A striking feature of the country between Rhiconich and Laxford Bridge is the number of perched blocks which crown the smooth crests of the bare gneiss ridges and stand out in relief on the sky-line.

General Characters of the Rocks.—The whole of the Lewisian rocks in the district under consideration belong to the unmoved area. They have not been affected by the great post-Cambrian thrusts, and their structures are to-day essentially the same as in pre-Torridonian times.

The gneiss of this northern district can in places be easily seen to consist of a fundamental complex invaded by granites and pegmatites, but this complex may not quite represent the early complex of the central district. In fact, as will be shown in the sequel, there is good reason for the belief that traces of both basic and ultrabasic dykes, in all probability referable to the period of intrusion of those of Scourie and Loch Inver, are to be found on Beinn an Amair, three miles south-west of Durness, and near Cape Wrath. As explained by Mr. Teall in a former chapter, great difficulty is sometimes experienced in this area in distinguishing between the biotite gneisses of the fundamental complex and some of the intrusive foliated granites. On Ben Amair, where the invading granite takes the form of dykes and sills which traverse the complex of basic and acid gneiss and modified dykes, all alike in the granulitic stage, there is no difficulty in separating the granite from the granulitic biotite-gneiss of the real original complex. In other parts of the district, however, where both groups of acid material have passed into the granular condition, it is almost impossible to distinguish between them. The granite presents no chilled margin, and seems to merge into the surrounding rock.

The gneiss of the original complex in this district includes three of the groups or sub-groups into which Mr. Teall has divided the Lewisian rocks:—

a. Grey gneiss, in which biotite is the predominant or only ferro-magnesian mineral (IV. 1).

b. Hornblende-biotite-gneiss, containing a considerable proportion of hornblende in addition to the biotite (III. B 1).

c. Dark gneiss, in which hornblende is the predominant mineral (III. A).

These three varieties alternate in bands or areas of varying breadth having, as a rule, no sharply defined boundaries, but graduating from the more acid into the more basic type as the proportion of hornblende present increases. In structure these gneisses are granular; but in places, as on the north slopes of Beinn Amair, they are in the granulitic stage. The hornblende-gneiss (*c*) which appears to preponderate in the area between Cape Wrath and Laxford Bridge is mainly composed of hornblende and plagioclase felspar, but generally contains a little pyroxene. The hornblende does not occur in bladed or acicular forms, but in stout crystals, almost as broad as long ("short crystallisation").

The numerous dark bands, masses, and lenticles of basic and ultrabasic material that occur with these gneisses cannot with any certainty be separated from them in point of origin, and must be regarded for the most part, at least, as portions of the original complex. This is particularly the case with the lenticular masses which are so abundant in certain areas, and often appear to be completely surrounded by the more acid rocks. These lenticles vary in size from small knots or "eyes" an inch or two across to masses many yards in diameter, and are wholly or in great measure composed of dark hornblende, but are often fringed or sheathed with a matted mass of crystals of a very black mica, probably haughtonite. The bands of basic material vary from a few inches to several yards in breadth. Their continuity in tracts where the later acid intrusions are prevalent is often interrupted by the injection of granite and pegmatitic material, with the result that portions of the basic rock are isolated in the form of lenticular masses, in whose linear arrangement the course of the band can still be traced. The lenticles thus produced differ, of course, in their origin from, and must not be confounded with, the original knots above described.

The fine coast sections in the Kyle of Durness and at Cape Wrath afford no satisfactory evidence as to whether or not these basic bands should be regarded as later intrusions in the original complex. They are foliated throughout in agreement with the common foliation of the gneiss amidst which they occur, and no unmistakable instance has been detected of the transgression of the foliation planes of the gneiss by the basic material. In the cliffs east and south of Cape Wrath, where the rocks are sharply folded, the dark bands follow the plications, which they make visible in a very conspicuous manner.

A short distance west from the Ferry House, in the Kyle of Durness, a good example may be seen of one of these bands of dark basic rock. It has somewhat the appearance of an intrusive dyke, though its relations to the gneiss are nowhere distinctly visible. It has been traced in a W.N.W. direction for a distance of nearly ¼ mile, and can be examined at several places along the side of the road to Cape Wrath. The rock of this band is thoroughly foliated, its nearly vertical planes dip south-west, while the mineral particles are arranged in lines indicating movement in one particular direction. The chief constituents of this rock are felspar and hornblende, with a little mica along the divisional planes. The relative amount of the first two minerals continually varies; some bands being highly felspathic, others more hornblendic, while there are also thin bands and lenticles of pure hornblende. Segregation of the various minerals is thus suggested. The whole mass is so singularly free from acid material, either original or introduced, as to suggest that it may be a later basic intrusion in the original complex, comparable to a "Scourie dyke." If such be the origin of the band its injection may have been posterior to the movements which produced the early folding and puckering, but anterior to those which gave rise to the cleavage foliation of the gneiss.

The later intrusive origin of certain narrow bands of basic rock with more or less parallel sides, that can be traced for several hundred yards on the summit and northern slopes of Beinn Amair, can be assumed with more certainty. They appear to transgress the different bands of the original complex both vertically and horizontally, and not to share in the folding of these bands but to follow an independent course that is more or less parallel to the direction of the planes of the longer axes of the folds both in their dip and strike. The rock near the sides of these bands is different in texture, and the ingredients are more intimately mixed than in the centre, which often has a mottled appearance from the arrangement of the quartz and felspar in small aggregates.

The behaviour of these basic masses, cutting as they do the banding of the gneisses of the original complex, while they not only share in a common foliation with them, but are now in identically the same state of crystallisation, points to the inference that they were injected into these gneisses when the latter had already acquired their banding, but prior to the time when they were subjected to the forces which produced their present foliation and puckering. As these bands have the same trend as the longer axes of the folds, they would also lie more or less at right angles to the direction in which these forces were applied. Hence they would not share in the puckering of the surrounding gneiss, though they would be compressed and foliated in a direction more or less parallel with the foliation planes of the gneiss, and differing from it only so far as the coefficient of friction of their material differed from that of the materials of the gneiss.

It is possible that other bands of this nature may occur in the northern area, with a trend different from that of the axes of the folds, and inclined at a less angle to the horizon. In such cases they would partly share in the folding of the gneiss, and hence would more easily escape detection. In those areas where the later granitic intrusions play a subordinate part, the banded gneisses are generally found to be thrown into a system of folds, whose long axes have a general north-west and south-east trend.* The axial planes of these folds may be vertical, in which case normal folds are produced, and the rocks either undulate at gentle angles or are sharply compressed, giving the appearance of verticality. More often they are oblique to the horizon, and the folding is consequently isoclinal. In this case the overfolding may become so extreme as to produce the effect of horizontality in the flattened limbs of the folds.

* It was, doubtless, this structure which led Murchison to insist on the north-west strike of the fundamental gneiss in contradistinction to the north-north-east strike of the eastern schists and flags.

The first type of folding occurs—in both varieties—at Cape Wrath; the second may be observed at several places along the west side of the Kyle of Durness, as, for example, at the mouth of the Kyle immediately south of Port Odhar.

In addition to this system of plication the banded gneisses further show a persistent foliation which traverses the different materials included in the folds in a direction more or less parallel to their longer axes. The mineral particles are arranged along planes which follow the same direction, but the banding is not destroyed. Hence we may infer that the whole of the material has been rearranged by the movements which resulted in the folding and foliation now apparent in these rocks.

The acid materials which have been intruded into the original complex of the gneiss are well displayed along the west side of the Kyle of Durness. They take there the form of massive pegmatites often many yards in breadth, and of thinner bands of fine or medium-grained granite. In parts of the section the rocks of the original complex bear a comparatively small proportion to the quantity of introduced material. The granite is not foliated, though a tendency to a linear arrangement or orientation of the minerals, especially of the biotite, can generally be detected. This lineation is often more or less parallel to the foliation of the gneiss, but sometimes lies at an angle with it of not less than 20°. The edges of the granite intrusions distinctly transgress the foliation planes of the gneiss, sometimes cutting them at a considerable angle, while the apophyses from the granite often penetrate the gneiss for several yards in a most irregular manner. Many inclusions of gneiss, of all sizes, likewise appear in the granite.

The pegmatite veins, which are evidently a phase of the same acid intrusion and derived from the same magma, cut the gneiss, the granite, and one another, and are often developed along the junction of the two rocks. The granite is decidedly acid in composition, the felspars being oligoclase and microcline, with biotite as the principal ferro-magnesian constituent: though in some cases, as, for example, in one or two bands north from Durness Ferry, a considerable amount of hornblende is also present. The pegmatites are extremely coarse, with large crystals of microcline. They contain biotite in large but scanty crystals, though these sometimes become more abundant along the edges of the vein.

In the neighbourhood of Cape Wrath, where these acid intrusions are largely developed, the rocks immediately below the lighthouse, and for some distance on either side of it, seem to be chiefly composed of granitic material which has invaded the original complex, the whole now forming a second granitoid complex, in which such portions of the early acid gneiss as remain cannot always be distinguished from the later acid intrusions. The basic portions of the original complex, which have to a greater degree resisted the invasion of the granite, retain their distinctive character and appear as knots and bands in the newer complex. The banded appearance of the rocks forming this complex, which is particularly marked in the ground immediately south of the Cape, does not appear to be due to the arrangement of the mineral constituents of the whole system in different layers, but rather to a rapid alternation of bands of unfoliated granite with other thinner bands and seams of foliated material belonging probably to the original complex. The whole assemblage of rocks in this part of the district may now be regarded as a series of composite or synthetic gneisses. A large portion of these may undoubtedly be referred to the later intrusion of granite, but this is combined with the acid gneiss of the original complex in such a manner that the rocks of the earlier and later origin cannot be distinguished from one another with any certainty. Both granite and original complex are cut by veins of pegmatite. They are, however, thin and very small in bulk compared with the granite. In this respect the Cape Wrath rocks are the reverse of those of the Kyle of Durness, where the pegmatites are largely in excess, and where we appear to be dealing with the edge of this area of intrusion.

DESCRIPTION OF THE DIFFERENT AREAS IN THE DISTRICT.

Cape Wrath.—The amount of peat and drift which covers the country immediately south and south-east of the Cape conceals the landward limits of the granite intrusions, and only in the sections afforded by the range of magnificent sea-cliffs can the extent and relation of the granite to the surrounding rocks be determined. The coast-line westwards from Geodha-na-Seamraig runs parallel to the general W.N.W. strike of the old granitoid gneiss, which, varied with a few dark basic bands, extends in an almost unbroken rampart to Clais Charnach. The western side of this inlet is formed by a great mass of red granite weathering grey, which on the landward side is intrusive in an extremely basic portion of the original complex.

The cliffs between this point and the Cape are also largely formed of the rocks of the granitoid complex, but contain numerous dark bands of basic material which, by their strongly contrasted tint, mark out the intense folding to which the rocks have been subjected (Plate V.). The vast sea-walls along this part of the coast are for the most part inaccessible either by land or sea, but in the inlet immediately west of the lighthouse—used as a boat harbour in calm weather—the rocks can be more closely studied. The original complex of the gneiss is there seen to bear but a small proportion to the amount of introduced material, which consists for the most part of a fine-grained grey or reddish granite, like that of the Kyle of Durness, and showing the same tendency to a linear arrangement of the biotite crystals. This rock occurs in bands of varying breadth, of which one that crosses the steep cliff immediately under the lighthouse must be at least 60 feet thick. The edges of the granite intrusions usually cross the foliation planes of the gneiss at gentle angles, but are often seen to cut off and isolate portions of the original complex. The pegmatite is small in amount compared with the granite. The larger veins traverse both the granite and the original complex, and run vertically up the face of the cliff.*

The folding in the gneiss is not so intense about Cape Wrath as it is in the cliffs further east. The nearly horizontal bands are thrown into gentle undulations, but are at times suddenly compressed into sharply puckered folds. The dark bands which share in this folding are often interrupted and isolated by the pegmatite veins forming lines of eye-shaped masses of basic material.

The rocks for some distance south from the lighthouse have already been described in the foregoing pages which discuss the general character of the granitoid complex. The edge of this area of acid intrusion seems to be reached about 200 yards north of A'Chailleach. In the neighbourhood of the fault which here brings in a small patch of Torridon conglomerate, rocks of the original complex again prevail, consisting of nearly vertical flaggy biotite-hornblende gneiss with a north-west strike. The sharp folds into which they have been thrown are well brought into view by the numerous conspicuous bands of black hornblende rock. A good deal of granitic material is still present here in the form of thin bands of medium-grained granite and veins of coarse pegmatite. The general character of the rocks resembles that of those on the Kyle of Durness, but the original complex is here of a considerably more basic type.

A peculiar and composite rock, which may have formed an ultrabasic dyke, occurs on the face of the cliff about 80 yards south from the fault, and immediately below the base of the Torridon conglomerate. It forms a lenticular vein or mass nearly 100 yards in length, running north-westward in a direction parallel to the strike of the gneiss. The northern end is chiefly composed of chert and massive blue hæmatite, the central portion of chert, and the southern part of serpentine, talc, and actinolite. The whole vein is characterised by stellate bundles of hydrous anthophyllite, with some asbestos. The chert and hæmatite are probably due to subsequent infiltration; the serpentine to decomposition of original minerals forming the vein.

Between the next inlet south from this point, where a small stream falls into the sea, and the fault, which again brings the Torridonian strata down to sea level, the amount of introduced granitic material once more increases, with a corresponding diminution in the bulk of the original complex, until the rocks resemble in general character those at the Cape.

* The geological world was first made acquainted with the complicated grouping of the rocks of this coast by the somewhat exaggerated drawing of "Gneiss and Granite Veins at Cape Wrath" given by Macculloch in Plate XXXI of his "Description of the Western Islands of Scotland" (1819). Some of the details of the cliffs, such as the feeble foliation of the granite veins in the same direction as that of the gneiss, the puckering of the bands of granite and pegmatite, and the way in which some of the lighter acid-veins wriggle upward through the gneiss, were illustrated by Sir Archibald Geikie in his Textbook of Geology.

Kyle of Durness.—That part of the western shore of the Kyle of Durness which lies between the Ferry House and Port Odhar at the mouth of Balnakeil Bay, displays the Lewisian gneiss in an excellent section which is continuous, save for the small area of Cambrian quartzite on either side of the Daill burn. Here the original complex consists of a series of well-banded gneisses in which the basic element perhaps predominates, the hornblendic variety being for the most part in excess of the more acid types. Here are also many bands and lenticles of basic and ultra-basic material, most of which must be regarded as forming part of the fundamental complex.

The later intrusions of acid material, which form so large a portion of the rocks in this section, have been already referred to in the general account of the rocks of this area (p 105). A typical example of the fine-grained biotite-granite intrusions of Loch Laxford type, which can be seen immediately south from the Ferry slip, forms a belt several feet in breadth, including bands of basic material and seams of dark mica that may have been portions of the original complex invaded by the granite. Pegmatite intrusions are also fairly numerous in this part of the section, though not so abundant as further north. The knots and thin veins of this rock are often sheathed with black mica, sometimes accompanied by dark hornblende in large crystals. Knots of these two minerals also occur within the pegmatite veins. The stream that falls into the Kyle ¾ mile north-west of the Ferry House has cut a deep ravine between the road and the sea. On the north bank of this gully, a short distance below the bridge, a lenticular mass of ultra-basic rock surrounded by granite material is well exposed.

The centre of this mass is composed of very dark hornblende, with bands of coarsely crystalline hornblende and mica; the edges consist of soft, decomposing, green hornblende and actinolite, with black mica and a talcose mineral. The rocks in the deep cove at the mouth of this stream, and for some little distance northwards of it, are much disturbed, reddened, and decomposed, being probably affected by the proximity of the Keoldale fault, which, immediately to the north, throws down the Cambrian quartzite.

On the further side of the Cambrian outlier the rocks are to a very large extent made up of later intrusive material, mostly in the form of pegmatite, which reaches its maximum development immediately south of Port Odhar. Many of the thin bands of fine-grained granite here show a linear structure parallel to the sides of the bands, due to the presence of thin parallel veins of pegmatite. About halfway between Dail and Port Odhar one or two thin granite dykes appear which differ somewhat in composition from the ordinary biotite granites of the area. A specimen (8507) † from one of them is described by Mr. Teall as closely allied to one

† Numbers within brackets in the description of rocks refer to the collection of microscopic slides made by the Geological Survey.

type of the Laxford granites, and is found under the microscope to be composed of microcline, biotite, hornblende, and quartz, with sphene and apatite as important accessories. The rock is remarkable for the large amount of microcline and sphene present in it. The rocks of the original complex in this part of the coast-section are similar in general character to those at the Ferry. Bands and knots of basic and ultra-basic material are largely developed to the south of the old landing slip 1½ mile north of Dail. Compressed vertical folding of the Cape type is characteristic of this part of the section, but at Port Odhar the rocks are thrown into flattened isoclinal folds.

Beinn an Amair.—Gneisses referable to the fundamental complex, and all in the granular or coarsely granulitic stage, make up the greater proportion of the rocks on this mountain. The basic portions which form the smaller part of this mass consist of hornblende-gneiss and hornblendite. An ultra-basic rock, of which a talcose mineral forms the chief constituent, may also be seen about 200 yards south of the summit-cairn. The acid rocks are chiefly biotite-gneisses, but often contain more or less hornblende and pass into hornblende gneisses, especially near their junction with more basic bands. The folding, for the most part of the isoclinal type about axial planes inclined at a high angle to the horizon, is often very sharp, though the folds are of no great depth.

In addition to the hornblendic gneisses of the original complex, certain narrow belts of similar rock may be, like others described in previous pages, later intrusions. Three of these dyke-like bands, having an E.S.E.-W.N.W. trend, occur within a distance of 400 yards from the top of the hill in a N.N.E. direction. Another band, probably a continuation of one of them, can be seen about 500 yards N.N.W. from the same point.

Granite and pegmatite veins are not so numerous on Beinn an Amair as along the shore of the Kyle of Durness. The granite occurs for the most part in distinct dykes from 2 feet to 20 yards in breadth, trending more or less in the direction of the foliation, but cutting obliquely across the banding and foliation-planes of the gneiss, and also transgressing the dyke-like basic masses. Good examples of this transgression may be seen in many places on the hill, the best being exposed on a bare ridge above half a mile to the N.N.W. of the top.

At the eastern end of this mountain mass, where the waters of the Kyle of Durness have laid bare a fine continuous section along the shore, the veins of granite and pegmatite are so numerous as almost to exclude the rocks of the original complex. What is seen of the older gneisses appears to be coarser in grain than where the granites are not so prevalent; while there is a greater preponderance of hornblendic gneiss than on the summit or higher slopes of Beinn an Amair.

Beinn a' Bhacaidh.—The eastern half of Beinn a' Bhacaidh, the hill immediately south-west of Beinn an Amair, is occupied by Cambrian and Torridonian strata; but rocks of Lewisian age rise in a more or less continuous bare ridge along its western face. The

PLATE XV.

Rock face—upper part consists of coarse pegmatite, lower part of Hornblende-Gneiss with parallel structure.
About one mile south of Rhiconich, Sutherlandshire.

veins of granite and pegmatite, which here make up the greater proportion of the rock, strike across this ridge in sharp contrast with the darker gneiss into which they are intruded, giving to the whole hill-face a peculiarly striped or brindled appearance when viewed from a distance. The gneisses of the original complex, though perhaps a little coarser in grain, are in much the same condition as those of Beinn an Amair.

North of the small lochan that lies high up on the mountain-side, the biotite-gneiss is in excess over the more basic type; but to the south of it large masses of hornblendic gneiss appear, in some places, almost to the exclusion of the acid gneiss. These basic masses seem to be the eastern extension of similar rocks which rise on the ridge south of Fasbheinn, on the further side of a peaty and drift-filled hollow, through which they cannot be traced. The dip of the foliation planes is more irregular than on Beinn Amair, and alternates between north-east and south-west. About 600 yards N.N.E. of the above-mentioned lochan a dyke-like mass of hornblende gneiss shows a finer grain near its edges than at the centre.

The most conspicuous feature on the ridge south of Fasbheinn just referred to, is the great preponderance of basic hornblendic gneiss over the acid portion of the original complex. Masses of hornblendic gneiss with bands of purer hornblende-rock form the greater part of the ridge, almost to the exclusion of the more acid gneiss. Where the acid and basic bands alternate, as they do near the south-east corner of Loch na Gainmhich, rapid overfolding, similar to that observed elsewhere in the region, is well displayed. The gneisses are cut by massive bands of granite and innumerable veins of pegmatite, but not to such an extent as on Beinn a' Bhacaidh.

To the south of Loch na Gainmhich the basic and acid materials of the original complex are more evenly distributed, and the gneiss is consequently banded or flaggy. Hence from the comparative scarcity of granite and pegmatite veins, the folding it remarkably well seen in this region. As the result of the constant repetition of the bands by folding upon vertical or highly-inclined axes a vertical or highly-inclined foliation has been produced, while the individual bands of the gneiss can be traced as horizontal or gently-inclined layers. As the granites and pegmatites often follow certain of these layers in preference to others, their outcrops are apt to resemble those of sills intruded among gently-inclined strata. This effect is more particularly seen in the manner in which they cap the summits, and partially or wholly encircle the slopes of the low hills south-west of Loch Gainmhich. A similar disposition of the pegmatite veins, accompanying rapid folding, is to be observed in the area immediately north of the mouth of Loch Sandwood and in the small Lewisian inlier on Cnoc Poll Mhurain. about a mile north of Sheigra.

Much of the central region south of Fasbheinn is obscured by peat and drift, the rocks being laid bare only on the hill-tops, and here and there along the streams. On the north side of Maol

Meallach Mòr coarse hornblendic gneisses enter largely into the original complex as on the hills to the north. Veins of granite and pegmatite abound, and sometimes show conspicuous graphic arrangement of the quartz and felspar.

The Amhainn na Buaigheal Duibhe, 4½ miles south-west of Durness, affords a good section for two miles above its mouth, showing highly corrugated hornblende and biotite-gneisses cut by innumerable granite and pegmatite-veins. Just above high-water mark a fine example of the intrusion of pegmatite along the weak limb of a fold can be observed.

A' Ghlasbheinn.—The rocks on this mountain are much decomposed and pervaded with lines of crush and fault, along which they are stained with hæmatite. A little to the north of the lochan on the summit a green hornblendic gneiss contains knots of radiating actinolite surrounded by mica. At a point about 200 yards north of this lochan the felspar of the pegmatites has been altered into agalmatolite. As this form of decomposition, as already stated, prevails characteristically round the margin of the Cambrian quartzite in the Loch Eireboll region, the inference seems probable that the top of A' Ghlasbheinn has but recently been denuded of its Cambrian covering. In fact, owing probably to the recent removal of the Torridonian and Cambrian strata, and the rotten state of the surface of older rocks over which they were deposited, it is not now possible to obtain an accurate knowledge of the unweathered condition of the Lewisian rocks over much of the area under consideration. Such is the case over most of the narrow belt of gneiss which extends north-eastwards from An Socach, 3½ miles north of Rhiconich. On the northern slopes of that hill large masses of hornblende-gneiss appear to form part of the original complex, since they are associated with veins of quartzo-felspathic material distinct from the later granite and pegmatite intrusions.

The ground along the north side of Loch Inchard, and between Rhiconich and the slopes of Foinnebheinn, has not been revisited since it was examined in the early days of the Survey of the North-West Highlands, when but little was known as to the nature of the Lewisian gneiss. It has therefore been thought better not to attempt here any detailed description of the rocks in those areas.

Rispond to Strath Dionard. From the shore between Rispond and Ceannabeinne west of Loch Eireboll, a belt of Lewisian gneiss about two miles in breadth extends southwards for a distance of ten miles to Strath Dionard. On the west it is bounded by the normal fault which throws down the Cambrian basin of Durness, and on the east it is overlain unconformably by the Cambrian quartzite of Loch Eireboll.

The rocks along this belt are the south-eastern prolongations of those already described that lie to the west of the Kyle of Durness. Apart from the later intrusions of granite and pegmatite of pre-Torridonian age, the members of the complex, which are well exposed in the above sections between Rispond and Ceannabeinne, comprise early basic knots and lenticles consisting of hornblende-gneiss or hornblende-biotite-gneiss, enclosed within more acid material which, containing abundant quartz and felspar, may be described as biotite-gneiss. Sometimes there appears to be a gradation from the one type to the other. The rocks are granular, and are characterised by short crystallisation. The members of the complex are arranged in well-defined parallel bands that have been folded on vertical or highly-inclined axial planes, which strike north-west and south-east. Striping is well seen on many of the nearly vertical faces, and particularly on the sea-cliff north-east of Ceannabeinne House, where the hornblende and biotite-gneisses in thin bands are rapidly plicated in moderately deep folds. There they dip to the north-east at 84°, and on one of these surfaces this lineation is inclined to the north-west at high angles.

These rocks are traversed by numerous veins, sills, and dykes of pink granite and pegmatite, the former containing oligoclase, microcline, quartz, biotite, and rarely muscovite. These later acid intrusions are more or less parallel with the strike of the granular gneisses and seem to be introduced in many places along the weak limbs of folds. Many of the granite sills and dykes show an orientation of the micas parallel to their margins; indeed, in some localities along the belt to Strath Dionard, the foliation is so marked that they resemble the older biotite gneisses of the complex. At Rispond, however, their intrusive character is apparent. The pegmatites traverse the granite-sills and do not show a similar orientation of the micas, but frequently an appearance of coarse mineral-banding. Dr. Heddle described a vein of graphic granite belonging to this series that occurs on the north shore of Rispond harbour, and displays a fine development of microcline and oligoclase, and contains also Haughtonite and magnetite.* The same mineralogist called attention to the fact that in the Lewisian gneiss between Rispond and Beinn Ceannabeinne, agalmatolite surrounds the crystalline portions of the felspar, which he attributed to a change of the oligoclase.† This type of decomposition, as above referred to, has been found by the Geological Survey to be characteristic of the surface of the old gneiss platform where it has been covered by the Cambrian quartzite.

At the head of Loch Eireboll and at the base of the eastern slopes of Beinn Spionnaidh and Crann Stacach the Lewisian gneiss has been laid bare near Polla by the denudation of the overlying thin cake of Cambrian quartzite. There the members of the complex have the same north-west strike. An exceptional type of rock is found in this inlier, essentially composed of microcline, green pyroxene, hornblende, quartz, and other constituents. (See the section on Petrography, Chap. IV. II.A 3.)

Within the belt affected by the post-Cambrian movements on the east side of Loch Eireboll various detached masses of Lewisian gneiss occur, most of which lie to the west of the out-

* *Mineralog. Mag.*, vol. IV., p. 224.
† *Ibid.*, p. 215.

crop of the Moine thrust-plane. Their relations to the Cambrian strata will be described in Part IV., only a brief reference being here made to their petrographical characters. The proofs that these detached masses really belong to the Lewisian gneiss have been already summarily stated in this volume in the section on Previous Literature.

In the small areas stretching south from Whitten Head (Ceann Geal Mòr) towards Freasgeal, the rocks consist of dark hornblendic gneiss, traversed by innumerable veins of granite and pegmatite, which are well seen on the northern sea-cliffs. Though the rocks are crushed in places they show their old structures, but their general strike, with some exceptions, is approximately north and south. The masses that run south from Inverhope by Hope Ferry to Ben Poll Ath-roinn (locally known as Ben Arnaboll) are composed of hornblendic and micaceous gneisses of the Cape Wrath types, intersected by veins and irregular masses of pink granite and pegmatite, the prevailing strike being in a north-east direction. Similar rocks appear on Creag na Faoilinn and Creag Earail beyond the head of Loch Eireboll. In these various areas the gneiss is traversed by numerous shear-planes, whereby the acid and basic materials have been sheared and mylonised.

Above the Moine thrust-plane an important band of reconstructed gneiss has been traced from the west slope of Beinn Thutaig south-west to Loch Hope and onwards to Meall a' Bhaid Tharsuinn. The rocks in this band dip to the south-east and have common foliation planes with the overlying Moine-schists. This zone and the faulted portions of the same mass in Sango Bay and at Fair-aird Head contain the type which has been described by Dr. Teall as zoisite gneiss.

DISTRICT BETWEEN LOCH INCHARD AND LOCH LAXFORD.*

The rocks in this peninsula resemble generally those above described in the ground to the north-east. The biotite and hornblende-gneisses which are regarded as part of the fundamental complex possess a granular rather than a granulitic structure. It is doubtful whether they include any pyroxene gneisses. They are associated with bands of hornblende-schist or dark hornblende-gneiss, which, in some places, behave like dykes, and in others, like parts of the early complex; hence it is uncertain whether they represent dykes of the "Scourie type." Granitic gneisses of intrusive origin, and pegmatites in which microcline is the predominant felspar, are very abundant. In the pale gneisses of the fundamental complex there is frequently a second foliation parallel to that of the later granite gneisses, from which it may be inferred that the characters of many of the early gneisses have been modified since the intrusion of the granitic bands.

In the tract now to be described the arrangement of the rocks

* By C. T. Clough.

differs considerably from that in the area further south—the north-eastern portion of the district extending from Laxford to Kylesku. In this portion the gneisses have a W.N.W. strike, with the limbs of fold and second foliation-planes dipping steeply S.S.W., while in the Laxford and Loch Inchard area it is only in the south-west half that a W.N.W. strike and S.S.W. dip prevail, and in the north-east part both strike and dip are variable, and the first foliation planes are sometimes flat.

Ultra-basic and Basic Rocks of the Fundamental Complex.—Examples of this group are to be found at the following localities:—About $\frac{2}{3}$ mile slightly west of south of Cnoc na h-Ula, between Rhiconich and Loch Laxford, a rock consisting chiefly of crystals of black hornblende and biotite extends about a hundred yards parallel to the strike of the neighbouring gneisses, the greatest breadth being about twenty yards. A smaller exposure of a similar type is seen nearly $\frac{1}{3}$ mile south of that hill. Another variety, consisting chiefly of large flakes of black biotite, traceable for at least a hundred yards, occurs rather more than $\frac{1}{3}$ mile slightly north of west of the south end of Loch-na-Claise Iuchairich.

Thin bands consisting chiefly of biotite, or biotite and hornblende, with small lumps and streaks of quartz and felspar resembling pegmatites, are common, which give rise to depressions and, in many cases, have formed lines of weakness, along which movement has taken place. The displacement has contorted the biotite-flakes along axial planes, which, in any one locality, all hade in one direction. Quartz veins and thin seams of gneiss sometimes occur in the bands, and are sharply contorted, though the gneisses above and below the bands are not affected. From the trend of the axial planes exposed about $\frac{1}{4}$ mile north of the north-west end of Caol Loch a' Mhin Ath—a point two miles south-east of Laxford Bridge—it may be inferred that the gneiss on the south-west side has been moved in a north-west direction. The proportion of biotite is sometimes greater near the margins of the bands than in the middle, and it seems possible that this mineral has been produced during the movements. In some places biotite is also common in thin streaks which traverse the more hornblendic parts, and which perhaps represent lines of movement.

Those basic rocks which can be referred with confidence to the early complex form irregular outcrops or eye-shaped lumps varying in diameter from an inch to more than a hundred yards. They occupy a large part of the ground at the following localities: between Loch Cròcach and Loch Ceum na Staidhreach, between Loch Inchard and Loch Mor Ceann na Saile, near the head of Loch a' Chathaidh, near Lochain na Creige Gile, one mile north of Loch Stack Lodge, and between the head of Loch a' Gharbh Bhaid Mhòir and Ben Arkle. In the coast section and inland cliffs, basic lenticles, several yards broad, are frequently enclosed by bands of paler gneiss, which become thinner just above or below the eye-shaped masses, so that the usual strike and dip are soon regained. Strings and irregular bands of pale gneiss traverse the early basic rocks, as for instance about 1⅓ miles slightly north of west of the head of Loch a' Gharbh Bhaid Mhòir, and 250 yards north of Loch Eileanach (two miles north of Loch Stack). In the former locality there are many dark inclusions in the pale gneiss, which were probably derived from a contiguous basic patch.

Some basic masses show no clear foliation or banding, and the white constituents are aggregated in small round spots, often about ¼ inch long; where apparent, it is usually but not always parallel to the margin. Occasionally garnets are abundant, and are generally of a port wine colour and without distinct idiomorphism. This mineral often occurs in small spherical aggregates mixed with granules of felspar and surrounded by a thin rim of similar granules. The aggregates are not usually more than ¼ inch long, but are sometimes so abundant as to form half the rock-mass.

Hornblende-gneiss.—The varieties of this rock, near and south of Loch Inchard, which have been examined under the microscope, are all referable to Group III., B. 1 (hornblende-gneiss proper), in which the hornblende is of a compact type and the structure granular. Most of the pale bands certainly belong to the early complex. These, together with thin alternating zones of biotite-gneiss, form a large part of the coast between Eilean na Saille and Rudh' a Cheathraimh Ghairbh north of Loch Laxford, and on the south-west side of Loch Inchard. Nearly the whole of the dark folia in the rock are formed of hornblende prisms, which are sometimes more than half an inch long and nearly as broad. The quartz is colourless and translucent, the felspar pale grey or pink. Some bands on the north-east side of the river Laxford, 300 yards below the bridge, and in other places, contain many grains and small crystals of yellow epidote. The hornblende and other minerals are fresh, and the epidote appears to be original. In an exposure of gneiss 200 yards north-east of Cnoc Glac na Stairne, about 300 yards east of Lochan na Cloiche, three miles west of Rhiconich, enclosed lumps about a yard long consist chiefly of epidote. On the top of Cnoc na h-Ula somewhat similar small knots, embedded in a grey gneiss, are composed of epidote and scapolite.

Biotite-gneiss.—Only three of the gneisses with biotite in excess of hornblende, in the area south of Loch Inchard, have been examined under the microscope. Two of these, one (2987) from the roadside north of Laxford, the other (3238) from a mile and 300 yards E.N.E. of Laxford Bridge, possess a granular structure, and in the third (3478) from the roadside a mile north-west of Laxford Bridge, the structure is partially granulitic. The gneisses of this group frequently contain small knots and lenticles, composed chiefly of hornblende. Their colour is generally pale, and the biotite is less in proportion than the hornblende in the hornblende-gneiss. Biotite rarely forms broad streaks.

A broad zone containing a large proportion of massive biotite-gneiss appears a little south of Loch Poll na Bà Baine, 1⅓ mile west of Rhiconich, and can be followed over Cnoc an Daimh to the coast south of Bagh Loch an Ròin. Some parts are so massive that perhaps in hand-specimens they might be taken for unfoliated granite. But a foliation with a prevalent S.S.W. dip at high angles is generally clear, and certain bands in the zone are folded into isoclines with limbs dipping S.S.W.

Large areas consisting chiefly of biotite-gneiss occur between Loch Sgeir a' Chadha and Loch na Caillich, south and south-east of Loch na h-Ula, south-west of Rhiconich, and on the east and south sides of the head of Loch a' Gharbh Bhaid Mhoir, 2¼ miles E.N.E. of Laxford Bridge, where the first foliation or broad banding is sometimes poorly developed, and the rock has a granitic aspect. Lenticles, consisting chiefly of hornblende and biotite, and swathed round by the first foliation planes of the gneiss, are abundant in places. In other localities there is an appearance resembling false-bedding, the minor laminæ in certain bands being disposed in waves, while those above and below are even and parallel to one another.

Basic Dykes.—Bands of hornblende-schist which may possibly represent dykes are often difficult to trace, being frequently traversed by pegmatites and granite gneisses. They have no general north-west direction like the well-marked dykes near Scourie. Where the gneiss strikes north-west their trend is almost the same, but elsewhere it is different. A little west of Loch a' Ghairbh Bhaid Mhoir several bands strike north-east, and between Cnoc Gorm Mor and Loch Crocach a band runs nearly north and south for half a mile. It is probable, therefore, that if these hornblende-schists represent basic dykes, they have been twisted since their intrusion. Some of them cut the adjacent gneiss in places, while not far off there are no indications of intrusion. These schists are often interrupted so as to form lenticular strips which seem surrounded by the gneiss, thus recalling the broken parts of certain "Scourie dykes," which are crossed by thrusts; but in most cases no such displacements can be observed. If the strips represent portions of dykes, the conditions prevailing in this area at, or subsequently to, the time of intrusion must have differed widely from those further south, for the thrusts truncating the intrusions have produced no recognisable change in the surrounding rocks.

As certain dykes of granite-gneiss have been continuously traced for several miles across the area in nearly straight paths, it follows that, if the strips of hornblende-schist represent portions of dykes broken by thrusts, these displacements must be earlier than the granite gneiss. Yet in the district south of Laxford several granite gneiss intrusions pierce the Scourie dykes, and both possess a common foliation.

Lithologically these schists differ somewhat from those usually composing the basic dykes in the Laxford and Loch a' Chairn Bhain area. They are less fissile and schistose, and contain hornblendes of stouter form. They are more fine-grained than many of the hornblende schists of the early complex, and their composition is more uniform. The foliation frequently crosses the margins of the bands, and is parallel to that in the gneiss—a phenomenon common both in the early basic rocks and in the "Scourie dykes." In some places a linear foliation or rod-structure replaces the plane-parallel foliation. Garnets are usually common, and frequently occur in small aggregates surrounded by a thin white rim of felspar granules. One of the doubtful bands half a mile slightly north of east of Badcall Quay, Loch Laxford, contains hypersthene and augite as well as quartz (4478), and is classed as a pyroxene gneiss, but the quartz is not opalescent like that in the pyroxene gneiss near Scourie.

The cliffs by the road east and north-east of Badcall Quay show several dyke-like bands, most of which are only a few feet thick. One, about 200 yards east of the store-house, cuts the foliation of a pale hornblende gneiss almost at right angles. The foliation in the gneiss dips S.S.W. at a low angle, while the sides of the dyke-like band usually dip steeply N.N.E., but become irregular near the top of the section.

Later Granite-gneiss.—Over the area between Loch Inchard and Loch Laxford the granite gneisses are less abundant than south-west of the latter loch. They increase, however, from north-east to south-west, and from north-west to south-east, until between Loch Stack and Ben Arkle they are specially abundant over an area of about two square miles. These rocks appear both as dykes and sills, and are not all of the same age, some of the former being later than some of the latter. Indeed, it is probable that all the granite dykes were not intruded at the same time.

Most of these gneisses or foliated granites are of a pale pink colour, and contain small flakes of black biotite parallel to one another and to the thin quartz streaks which help to define the foliation. In some thick bands between Loch Stack and Loch an Fhionn Leathaid there is some hornblende as well as biotite. Small grains of magnetite or ilmenite are also occasionally observed. The predominant felspars in these rocks are oligoclase and microcline.

Most of the bands are distinctly foliated throughout. In some places the foliation crosses the margins and is continuous with the second foliation in the earlier gneisses; but usually, both in dykes and sills, it is parallel to the sides.

The sills are specially abundant W.N.W. of Loch Stack, where the largest examples occur, one on the north side of that loch being at least 160 yards wide. The thick sills are generally coarsest in grain, and usually contain many thin pegmatites, about half an inch thick, and parallel to the foliation. Besides the nearly vertical sills and dykes there are gently inclined sheets, an example of which occurs about ⅓ mile W.S.W. of the head of Loch an Tigh Sheilg, four miles E.N.E. of Laxford Bridge, where an intrusion of granite gneiss, with an almost horizontal base, cuts the vertical bands of an earlier gneiss. The foliation in this intrusive gneiss hades south-west, striking against the base, and there is a parallel second foliation in the earlier gneiss.

The general direction of the dykes is somewhat north of west, slightly nearer west than the strike of the earlier gneiss nearer

A portion of the rock shown in Plate XV., exhibiting the intrusive character of the pegmatite.
One mile south of Rhiconich, Sutherlandshire.

Laxford, and of the basic dykes on the south side of this loch. Some, however, strike east and west, and a few run north-east. One of the W.N.W. dykes has been traced from the west slope of Ben Arkle to the coast south-east of Eilean Meall a' Chaoruinn, a distance of nearly five miles. Near its south-east end the width varies from 60 to 40 yards, diminishing in a north-west direction. It splits in two branches N.N.E. of Badcall Quay, and is joined by others of varying width at different points. It cuts the first foliation planes of the adjacent gneiss along the whole of its course. About half a mile E.N.E. of Loch Airidh a' Bhaird, two miles north-east of Loch Stack Lodge, the foliation in the dyke is parallel to its margins, but the bands in the earlier gneiss on the south side are nearly flat: no second foliation in the earlier gneiss parallel to the foliation in the dyke has here been detected. In another locality, however, rather more than half a mile slightly east of south of the head of Loch a' Gharbh Bhaid Mhòir, where the broad bands of the older gneiss are nearly flat, a second foliation has been developed parallel to the side of the dyke and its planes of foliation.

S.W.

N.E.

FIG. 1 ($\frac{1}{60}$).—Granite-gneiss intrusion above and cutting the early banding of an older gneiss. The foliation in the granite-gneiss is parallel to the second foliation in the older gneiss. At the south-west end of the section this second foliation coincides in direction with the early banding. A third of a mile W.S.W. of the head of Loch an Tigh Sheilg.

In a dyke ⅓-mile E.N.E. of the south-east end of Caol Loch a' Mhìn Ath, 2¼ miles E.S.E. of Laxford Bridge, the foliation is not parallel to the side, but almost in the same direction as the bands of the earlier gneiss which it traverses. In this case the latter are supposed to represent both the first and second foliation planes. About a third of a mile south-east of the head of Loch a' Gharbh Bhaid Mhòir a thin dyke of granite gneiss cuts a broader sill of the same material, and is accompanied with a displacement of two feet. The foliation in the dyke is parallel to that in the sill and also to the sides of the dyke, but at a considerable angle to the sides of the sill.

In a section ⅝ mile E.S.E. of the head of Loch a' Gharbh Bhaid Mhòir the early gneiss and some thin foliated granite sills are folded, both limbs inclining south-east at gentle angles. Alike in these sills and the early gneiss there is a foliation, almost parallel to the axial planes of fold, which crosses the margins of the sills. Hence it may be inferred that the development of these common planes of schistosity was subsequent to the folding. It is uncertain whether the granite dykes have been folded in like manner.

The rarity of thick pegmatites in the granite dykes and the fact that the latter, in some cases, cut the pegmatites, suggest that many of the dykes are later than some of the sills. For example, by the road 200 yards south-east of Badcall Quay a granite-gneiss dyke, about a foot thick, cuts three pegmatites; and about 1,000 yards S.S.W. of the head of Loch a' Gharbh Bhaid Mhòir, a thin dyke foliated parallel to the side intersects several pegmatites.

About 200 yards S.S.E. of the outlet of Loch a' Bhlar Locha, and rather more than ½-mile north-east of the head of Loch a' Gharbh Bhaid Mhòir, some thin dykes of granite-gneiss are accompanied with displacements which affect the pegmatites, the dykes being foliated parallel to their sides, but not crushed.

FIG. 2 ($\frac{1}{100}$). — Granite-gneiss dyke cutting banded gneiss and pegmatite (cross-hatched). One branch of the pegmatite has been introduced along a limb of a fold. The pegmatite shows no appreciable foliation, but in the granite-gneiss dyke there is a foliation about parallel to the sides. About 1000 yards S.S.W. of the head of Loch a' Gharbh Bhaid Mhòir.

Pegmatites are common everywhere in the Laxford district, and specially abundant near the north end of Ben Arkle. The thickest bands occur near that mountain, also in the peninsula south of Loch Dhugaill (where some of them are 60 yards wide), and about ⅜-mile S.S.W. of Cnoc na h-Ula. Most pegmatites are parallel to the first foliation planes of the gneiss, and when the latter are folded they follow the fold. Hence, in the peninsula south of Loch Dhugaill, and elsewhere near Loch Laxford, the strike is W.N.W., while near Loch na h-Ula, and on the east side of the road a mile S.S.E. of Rhiconich some outcrops are nearly circular. (See Plates XV. and XVI.)

A number of pegmatites behave like dykes and cut the banded gneisses and hornblende schists. When the pegmatites are thin, so that both sides can be seen at once, they sometimes appear as lines of fault though uncrushed, as for instance on the roadside a little north-east of Badcall Quay. Again, about a mile slightly west of south of the head of Loch an Tigh Sheilg, N.N.W. of Ben Arkle, a thin pegmatite sill is crossed in a distance of a few feet by three small pegmatites, each hading south-east at 45°, and behaving as a reversed fault or thrust. These must have been formed after the sill. That the pegmatites are not all of the same age is also shown by the fact that some are earlier than certain intrusions of granite gneiss, while others are later. Some pegmatites have a tendency to expand suddenly here and there into a series of lenticles or knots connected by narrow veins, and surrounded by attenuated bands of gneiss. In some places small lenticles of pegmatite seem isolated in the gneiss—a feature common in rocks that are unusually rich in black mica, the contrast in colour enabling them to be readily perceived. Examples occur 140 yards west of the mouth of the burn that drains Loch Sgeir a' Chadha, 1¼ miles south-west of Rhiconich, and near the south end of Loch Ceum na Staidhreach, 2½ miles W.N.W. of Rhiconich.

The chief felspar in the pegmatites is microcline of a pale red colour. In the crags nearly a mile E.S.E. of the head of Loch a' Gharbh Bhaid Mhòir it shows conspicuous chatoyant lustre, and some of the cleavage faces exceed a square foot in area. Quartz is usually in much smaller proportion than felspar, but in a few thin bands, as for instance on the east side of Cnoc an Rudha, Loch Inchard, it is in excess. In a pegmatite, three inches thick, near the coast 170 yards north of the mouth of Loch an Roin, the exterior is composed almost wholly of felspar and the interior of quartz. Black mica is more common than white. In a pegmatite on the coast 350 yards south of Eilean Dubh, near the entrance to Loch Inchard, it forms large flakes two inches broad, which coalesce into irregular lumps and short strings.

Specks and streaks of black iron ore, apparently ilmenite, occur in the pegmatites between half a mile and a mile and a quarter S.S.E. of Cnoc na h-Ula, east of Loch Laxford; also in the pegmatite with strings of black mica near Eilean Dubh, and in other localities.

Two pegmatites displaying an arrangement of their constituents parallel to the sides have been already mentioned. In others the grain varies in different bands, the marginal ones being in some cases coarser, and in others finer, than the middle layer. More rarely, as in an instance on the coast a little north-east of the mouth of Loch an Roin, Loch Inchard, five bands may be distinguished, each nearly parallel to the side.

Thin pegmatites with a foliation crossing from side to side have been noted at the top of Cnoc na Suil Chruthaiche, north side of Loch Laxford, and nearly ⅓ mile slightly south of west of that eminence, ⅓-mile slightly east of north of the head of Loch an Tigh Sheilg, one mile north of Arkle, and elsewhere. In the first locality the quartz is arranged in thin parallel streaks crossing the pegmatite; in the second the pegmatite, about two inches thick, is in a dyke of granite gneiss and is disposed in sharp folds striking north-west, the foliation both in the gneiss and the pegmatite being parallel to the axial planes of the folds. Distinct foliation is rare in the coarse, thick pegmatites, in spite of the fact that the dykes of granite-gneiss, which are probably later than many of the pegmatites, are always foliated. During movements the thick pegmatites appear to have behaved as massive grits which, as is well known, have often remained uncleaved, even when the shales intercalated among them have been altered into slates.

Effects of Pre-Torridonian Movements on the Gneiss.—Thin streaks of red, purple or black, compact rock, like halleflinta, often crowded with pieces of hornblende-schist and gneiss, have been observed in many places near Loch Inchard. A quarter of a mile north and half a mile slightly west of north of the west end of Eilean an

The region west of the post-Cambrian thrusts may be divided into three belts, which are not sharply separated from one another, and whose long axes run in a W.N.W. and E.S.E. direction. In the north-eastern belt, varying from half a mile to a mile and a half in width, most of the gneisses of the fundamental complex are granular in structure and strike W.N.W. with a steep dip towards the S.S.W. They are traversed by intrusions of granite-gneiss and pegmatite which are so numerous that, taken together, they probably exceed in bulk the rocks of the complex. The south-west boundary of this belt runs from the south side of Rudha Ruadh, near the southern headland of Loch Laxford, by Creag na Fionndalach to a point about ⅓-mile north of Loch na Claise Fearna, where it is shifted southwards for a distance of 200 yards by a N.N.E. fault. Thence it trends E.S.E. by the north slope of Ben Stack to the Cambrian escarpment. This boundary line, over part of its course, crosses the foliation planes of the gneiss, The middle belt, averaging two miles in width, has its south-west margin defined by a line extending from the south side of Ben Dreavie, by Clar Loch More, Cnoc na Glaic Moire, and the north-east side of Cnoc Michie to a point on the coast about half a mile S.S.W. of Tarbat. This boundary also crosses the foliation of the gneiss. Here the petrographical character of the gneisses is more or less granulitic, although not sharply marked off from those to the north, and their strike is similar. They are pierced by basic dykes now generally occurring as hornblende schists and by subordinate intrusions of granite-gneiss and pegmatite. Lines of disruption traverse the area which have deformed the gneiss and dykes.

The south-west belt, from four to five miles in breadth, stretches south to Loch a' Chairn Bhain and Loch Glencoul. Here the rocks of the fundamental complex consist largely of pyroxene-gneisses with a variable strike; indeed, their foliation planes often dip at gentle angles and sometimes are almost flat. They are intersected by numerous basic dykes, which in many cases are either free from foliation or only slightly deformed. It was in this area that Dr. Teall, when examining one of these dykes near Scourie, obtained evidence of the metamorphosis of dolerite into hornblende-schist. Pegmatites are comparatively rare, and the existence of rocks that represent the granite-gneisses of the other belts is uncertain. This tract is characterised by numerous shear lines or thrusts, whereby the dykes have been deflected, displaced and deformed, and new petrographical characters have been developed alike in the dykes and gneiss. Near these lines of disruption and contortion both the dykes and gneisses lithologically resemble those in the middle belt, though near some of the thrusts they are more finely foliated and granulitised.

In the middle belt the alteration of the rocks has been accompanied by many sharp contortions, with axial planes striking W.N.W. and dipping steeply towards S.S.W. Near the boundary between the middle and south-west belts there is usually an area, from a quarter to half a mile broad, in which the contortions with axial planes striking W.N.W. gradually increase in intensity and number in a N.N.E. direction. But on the coast half a mile S.S.W. of Tarbat the boundary between the two is tolerably sharp, perhaps because on the north-east side of the boundary the lines of thrust and contortion, which probably produce the granulitisation of the gneisses, are close together, while on the south-east they are separated by wide spaces in which the gneiss is almost flat or dips north-west.

In certain tracts of the middle belt the gneisses have largely escaped the influence of the pre-Torridonian movements, and resemble lithologically the original types so common in the south-western area of the district. Such an area occurs a little north-east of Clar Loch Mor. It is probable that many of the gneisses and dykes in the central part of the district have been derived from the alteration of rocks like the less altered types in the south-western area. In regard to the origin of the granular gneisses in the north-eastern belt the difficulties in coming to a conclusion are greater, for under the microscope these gneisses show no structures which prove them to have been at any time in a less altered condition than now. The belt is, however, so permeated by foliated granite and pegmatites that it does not seem likely that the gneisses of the fundamental complex can have escaped alteration. The field-evidence would rather lead us to suppose that they are even more altered than the gneisses in the other belts. For it can be shown that in the south-western belt the gneisses are always more altered in the areas where the dykes are foliated. Now, in the north-eastern belt the granitic intrusions are always foliated, and this foliation can hardly be considered to represent flow-structure, for in many places it crosses the sides of the intrusions for great distances and at considerable angles. Some of the granitic intrusions occur also within basic dykes and the foliation-planes in the one rock continue into the other.

In the south-western belt the granulitic micaceous gneisses have for the most part been formed not from granular biotite gneisses, but from pyroxene gneisses or from pyroxene hornblende gneisses, and the granulitisation is accompanied with a diminution, or disappearance, of the opalescence of the quartz streaks. In the middle belt quartz streaks with distinct opalescence are rare, and in the north-eastern, perhaps, they never occur.

Strains induced during folding determined the direction of the foliation in the granite-gneisses and the second foliation in the gneisses of the fundamental complex. But in the north-eastern belt the folds are not accompanied by distinct granulitisation. The absence of definite thrusts and zones of granulitic gneiss suggests that at the time the thrusts were being formed in the other belts the gneisses in the north-eastern belt may have been comparatively plastic. The absence of granulitisation and the abundance of pegmatites in this belt may possibly be connected with the great thickness of cover under which the rocks there may once have lain. The axial plains of the folds in both the middle and north-eastern belt constantly hade S.S.W., and as we proceed from Laxford in a

S.S.W. direction we cross from lower to higher planes of second foliation.

It seems probable that at a certain pressure, or depth, definite lines of fracture could not be formed, any fissure that might be commenced being at once filled by inflow of material from the sides.* Perhaps this may explain why definite thrusts have not been recognised in the north-eastern belt. The supposition that the rocks of the middle belt may once have been under a thicker cover than those of the south-western may also account for the chief differences between them, the folding in the former being general, while in the latter it is chiefly confined to the neighbourhood of certain thrusts.

ROCKS OF THE FUNDAMENTAL COMPLEX.

Ultrabasic Group.—In the north-eastern belt the most conspicuous ultrabasic rocks consist of thin bands and lenticles of hornblende mixed with biotite in varying proportion. In some examples biotite occurs in excess of hornblende, or alone. The hornblende is black in hand-specimens, and occurs in large stout prisms. The biotite, when fresh, has the same tint and forms large flakes. Near the margins of the lenticles biotite is most abundant; indeed, these may consist wholly of that mineral, while the interior portion is entirely of hornblende. In some bands, strings of biotite traverse the more hornblendic, central portions. Such phenomena are seen in lenticles close to the road half a mile north-west of Airdachuilinn. These bands of ultrabasic rock, though in some places several yards wide, usually do not exceed a few feet. Even where thin they often give rise to conspicuous topographical features, forming the under parts of scars or deep trenches, as for instance on the south side of Laxford Bay, near high-water mark about 250 yards south-west of the storehouse, and within a distance of 80 yards further to the south-west. Others occur along the strike of these in an E.S.E. direction, between the bridge and the bend of the river, and continue past Caol Loch a' Mhin Ath and Caol Lochan.

That movements have taken place along most of these bands is shown by the contorted condition of their folia, while the gneiss at their sides is free from contortion. A band which appears half a mile slightly north-west of the foot of Caol Loch a' Mhin Ath shows rapid isoclinal folding with axial planes striking at angles of about 45° against the adjacent gneiss. The folds are best shown by thin, hard, pale gray folia which occur within the biotite hornblende rock, but also by the biotite flakes in the rock itself. From the position and inclination of the axial planes it would appear that the rocks on the south-west side of the band had been moved in a north-west direction past those on the north-east.

In the middle belt, particularly in the north-eastern part where

* See Van Hise, "Principles of North American Geology." Sixteenth Annual Report of the United States Geological Survey, p. 593.

Foliated pegmatite containing large "eyes" of microcline. Ard Shieldaig, Loch Torridon, Ross-shire.

they are numerous, these hornblende-biotite bands are well exposed on the coast a third of a mile south of Rudha Ruadh, 350 yards north of the foot of Loch Dubh (one mile south-west of Loch Laxford), and on the roadside 200 yards below Loch na Claise Fearna (1½ miles south-west of Loch Laxford Bay), and rather less than half a mile south-west of Badnabay. Thin bands weathering with a rough brown surface are common, particularly within or close to the garnetiferous basic rocks, the roughness being chiefly due to projecting crystals of pyroxene and hornblende. A specimen from an exposure ⅓-mile N.N.W. of Tarbat proved to be a banded hornblende-pyroxenite with a little olivine passing into serpentine, and containing parallel seams of hornblende from one to six inches thick.

Ultrabasic rocks weathering partly with an orange crust and containing many specks of serpentine have been traced for considerable distances between Achfarry (one mile south of Loch Stack) and Loch Eileanach. The serpentinous portions sometimes pass along the strike into rocks resembling pyroxenites, and may also be associated with others consisting chiefly of interlacing colourless needles of anthophyllite. Hand-specimens of some of the serpentinous parts show no indication of foliation, but others are finely fissile and lustrous with white mica or talc. An acid gneiss which occurs half a mile north-west of Loch na Gualainne contains lumps, from a few inches to several feet long, chiefly composed of hornblende, the crystals of which are arranged in layers parallel to the long axis of each lump. These layers, however, do not continue quite to the sides, there being a peripheral zone, perhaps half an inch thick, which on weathered surfaces projects somewhat from the interior, and in which the hornblende crystals are disposed at right angles to the sides. This disposition suggests that the peripheral zones have been melted and recrystallized after the lumps had been caught up by an igneous rock which is now represented by the acid gneiss.

In the south-west belt hornblende-pyroxenites are seen in the following among other places:—Close to the north-west side of the road west of Cnoc na Glaic Moire (1½ miles E.N.E. of Scourie); the path ⅝-mile E.S.E. of the top of Ben Strome; the hill half a mile slightly south of east of Ben Strome, and the south-west side of the great area of garnetiferous basic rock between Ben Strome and Loch na Leathaid Bhuain, both localities being north of Loch Glendhu. Outcrops of hornblendite and pyroxenite are also numerous in the neighbourhood of Scourie, usually associated with, or surrounded by, basic rocks containing abundant garnets. The larger ultrabasic masses contain for the most part both varieties of rock, but the proportions between the different constituents vary much in the different outcrops. The mode of occurrence is also variable. In some instances, as in the mass forming the island in Scourie Bay, much of the rock is a granular aggregate of pale green diallage and hornblende, while in other cases, as in the remarkable banded rock described by Dr. Teall (p. 47), the hornblendite and pyroxenite form more or less separate bands. The rocks are generally coarse in grain and dark green or black in colour. Olivine is not a common constituent of these rocks, having only been found in one specimen from the mass to the north-west of Pairc a' Chladaich, north side of Scourie Bay, but pleonaste or spinelle seems to be a common accessory in the ultrabasic masses on the north side of that bay. The largest of these masses occurs on the north of Scourie House, where it shows a breadth in one place of about 130 yards, but it cannot be traced for more than a quarter of a mile. Like all the other bands under description, its strike coincides in the main with that of the adjacent gneiss. It is not entirely made up of ultrabasic material. A part of it is beautifully banded like the case described by Dr. Teall. Other examples of these ultrabasic rocks occur about a quarter of a mile north-west of Scourie House, where they dip north-west at angles from 40° to 50°.

Nearly a mile south of Scourie, in the neighbourhood of Lochan Daimh Mor, one of the largest ultrabasic masses in the district is to be seen. Its boundaries are not well defined, but it stretches from the south end of the loch in a S.S.E. direction for about a quarter of a mile, and it has apparently a breadth of from 70 to 100 yards. It appears to be mainly composed of serpentine and peridotite which is bordered on the west by a garnetiferous hornblendic rock, but one specimen from this area (4893) is described as a crystalline granular aggregate of enstatite (hypersthene rock). Fifty yards south of the main mass of serpentine an oval-shaped mass of the same rock about 100 yards in width may be observed. Its greatest length runs nearly parallel to the general strike of the foliation in the adjacent gneiss, while that of the main mass crosses the general strike nearly at right angles. Two narrow bands of gneiss appear in the ultrabasic mass near the loch, their strike being parallel to the length of the mass, so that probably a local variation of the strike of the gneiss takes place here round the borders of this ultrabasic mass.

About a quarter of a mile S.S.W. of Lochan nam Breac, Geisgeil, another patch of ultrabasic material presents a somewhat varied character. While the greater part of it is composed of an aggregate of anthophyllite and carbonate, it includes a massive rock of uniformly fine texture and dark green colour made up of olivine, which has been slightly serpentinised along cracks, and has the usual branching strings of iron-ore. This is the most typical dunite which Dr. Teall has met with in the British Isles. Only one small grain in the microscopic slide is not referable to olivine, and is probably enstatite. The aggregate of anthophyllite and carbonate forms a grey rock weathering brown from the oxidation of the iron in the carbonate. The anthophyllite is colourless and fibrous, without definite terminations. About three-quarters of a mile north of this locality another outcrop of anthophyllite-rock has been noted similar to that here described, but less decomposed. The interlacing prisms of anthophyllite are conspicuous on the surface where the carbonates have been removed by weathering.

A few small lenticular masses and thin bands of rock that resemble peridotite occur along the north shore of Loch a' Chairn Bhain and on the island of Calbha Beag. One of these, at the west end of Duartmore Bay, is affected by a line of thrust and sheared into an unctuous schist.

On the south shore of Loch Glendhu, about a mile and 300 yards E.S.E. of Kylesku Inn, a mica-anthophyllite rock (2955), containing grains of dolomite and specks of pyrites, wraps round several nodules which are much more calcareous than itself, and consist chiefly of magnetite, spathic iron, and dolomite, but contain also abundant films of white mica, or talc, brown biotite in small nests, a little green hornblende and secondary quartz. One of the nodules is six feet long and two broad. On the island 300 yards S.S.W. of Kylestrome other calcareous lenticles were also noticed, in which anthophyllite has not been detected.

Early Basic Rocks.—In most parts of the fundamental complex of this district rocks containing felspar, and for the most part without quartz, except in scattered strings, are abundant, and vary greatly in character, as is shown by the abundance or paucity of garnets and of strings and irregular folia rich in quartz. Save in the north-eastern belt these rocks and the basic dykes can generally be distinguished here, even when the junctions with neighbouring rocks are not visible. Almost every good exposure of the basic type shows garnets in some part or other, also strings with opalescent quartz, but only a few basic dykes are garnetiferous. In these latter cases the garnets are small and rare, while quartz veins also are not common save when the rocks have been foliated, and then the quartz is less opalescent than in the early basic group. There is no doubt that in this district the great development of garnet preceded the intrusion of the dykes.

Most of the early basic rocks may perhaps be classed either as pyroxene-granulites or garnet-amphibolites.* These rocks frequently project in the landscape. They also form knots, sometimes in groups, surrounded by the acid gneisses, and are well developed in areas where the basic dykes are not foliated. These knots must have been formed before the intrusion of the dykes. Their longer axes are generally parallel to the strike of the adjacent gneiss, but not always.

In the north-east belt the members of this group do not form large areas. Perhaps the chief exposure is that on the hill rather more than ⅓-mile S.S.E. of Badnabay, which is folded along north-west axes, and traceable for about 600 yards, its maximum width being about 60 yards. It is much traversed by veins of granite-gneiss. In the middle belt the early basic rocks are widespread, and perhaps form half the area of the north-east portion. Near Loch na Gualainne and the north end of Loch nan Breac, south of Loch Laxford, garnetiferous rocks are intimately mixed with pale gneisses. Again, ⅜-mile E.S.E. of Fanigmore, south of Loch Laxford, masses of basic rock are traversed in all

* Mr. Harker has described a specimen from about three miles south of Laxford Bay. *Geol. Mag.*, 1891, p. 171.

directions by thin strings of acid pale grey or reddish gneiss, so that portions of the former are isolated by the latter. The veins are often only an inch or two thick, but so numerous that they almost equal the dark rock in bulk. No acid strings penetrate the basic dyke near the north-east ends of Loch na Gualainne and Loch nan Breac, from which it may be inferred that they are older than this dyke and not of the age of the granite-gneisses of Laxford.

That the acid gneisses of the early complex have in some places invaded and surrounded a basic rock, which, if not already completely solidified, at least possessed a banded structure, is shown by the occurrence in them of banded basic inclusions, which are truncated by the surrounding folia of acid gneiss. Bands of unusually acid character are so frequently found at the edge of, or within, masses of basic or ultrabasic rock as to suggest that the two rocks may have been segregated from one magma, the rock next the basic mass becoming more acid in consequence of the abstraction of the more basic minerals.

As the development of garnets mainly preceded the intrusion of the dykes, it must also have been anterior to the thrusts and contortions by which the dykes and pale gneisses have been so greatly modified, yet the garnets and the rocks containing them appear for the most part to have escaped alteration. The rocks in most of the large basic exposures are hard and massive, and not well banded, and the thrusts have often proceeded round their sides instead of crossing them. The garnets in the basic rocks on the north-west side of Loch na Gualainne vary in abundance and size in different bands. They are of a port wine colour and of great brilliancy, but never show good idiomorphic outlines, being usually aggregated into lumps and intergrown with hornblende, felspar, or ilmenite. One such lump measured six inches in breadth and six and a half in length.

In the south-west belt the largest exposures of early basic rock occur on the north-west side of the south-west portion of Loch an Leathaid Bhuain, north of Loch Glendhu, where they are much mixed with pale gneiss, but over an area of perhaps a square mile the basic rock is considerably in excess of the acid. The north boundary of the main basic area is clearly defined for about half a mile east of the path, and, though curved, has a general east and west direction; west of Maldie Burn the south boundary is also tolerably clear for nearly a mile. In a large part of the rock no banding can be perceived. The garnet aggregates are numerous and sometimes three or four inches long, and intergrown with ilmenite. There are many irregular, pale grey streaks consisting chiefly of opalescent quartz.

The hypersthene-augite-plagioclase rocks which are garnetiferous in the Scourie district seem always to occur in close connection with the hornblendites and pyroxenites. They are generally almost black, and form a border to the ultrabasic masses, but may sometimes occur independently. Here, again, the garnets, often as large as one's fist, are always cracked or broken. Those portions of the rock which are free from garnets belong to the Baltimore gabbro type, and occasionally (as in No. 2990 from the shore north-west of Scourie Mor) a rock which contains garnets, but without hypersthene, is a gabbro in structure and composition. In addition to the minerals mentioned above, hornblende is often present, and is sometimes as important a constituent as any of the others. The other early basic rocks near Scourie which occur as knots in the gneiss are probably more hornblendic than augitic in character. None of these masses is of great size except that which occurs four miles south of Scourie and about half a mile east of Loch a Mhuilinn. Much basic material is enclosed in the gneiss to the west of the north end of Clar Loch Cnoc Thormaid, about three miles E.S.E. of Scourie, and along the strike of the gneiss W.N.W. It is noticeable, too, between the south end of Clar Loch Cnoc Thormaid and Loch nan Uidh, and on the north side of the eastermost bay of Loch Crocach.

Pyroxene-Gneisses, Pyroxene-Hornblende Gneisses, and Gneisses with Biotite in Aggregates.—Gneisses in which the pyroxenes are not associated with hornblende are probably rare, but the pyroxene-hornblende-gneisses in which hornblende occurs in aggregates and has apparently replaced pyroxene are common in the south-west belt, and perhaps cover a larger surface there than any other rock. They closely resemble the pyroxene-gneisses proper, and occur with them in those places where the basic dykes are most free from foliation, and in which there have been no great pre-Torridonian movements since the intrusion of these dykes. The same areas display gneisses with aggregates of small scales of biotite, but these gneisses appear to occur sporadically, and are connected by imperceptible gradations with the pyroxene-hornblende-gneisses.

The dip of the gneisses belonging to these three types is usually towards W.N.W.—a direction which prevails over most of the area between the Sound of Handa and Loch na h-Airdh Sleibhe, in many places south of Scourie, on the coast near Kylestrome, and on Loch Glendhu. Along the shore from Scourie Bay to Badcall, and again from the south side of Badcall Bay to Allt an Strathain the general dip is west or north-west. Some miles inland, however, it becomes irregular. The gneisses between Loch na h-Airdh Sleibhe and Loch Crocach, for example, have been thrown into a series of folds, the axes of which run W.N.W or north-west, the gneiss being sometimes horizontal, sometimes undulating gently, and in places vertical, with a strike parallel to the axes of fold. A fold of this kind on a somewhat large scale crosses the whole district from Badcall Bay in a south-east direction through Geisgeil to near the north end of Loch Crocach. Near the east end of Loch na h-Airdh Sleibhe, on the south-west and south-east sides of Cnoc Odhar (a hill three miles N.N.W. of Kylesku) and on the south-east side of Druim na h-Imrich (north of Loch a' Chairn Bhain), the banding of the gneiss is nearly flat. Between Ben Auskaird and Loch Clach a' Chinn Duibh, 2¼ miles N.N.E. of Kylesku, it generally dips north between 10° and

30°. Between Druim na h-Imrich and Cnoc Chalba, 4 miles north-west of Kylesku, the gneisses, save near the pre-Torridon shear lines, usually undulate at low angles and are often thrown into low domes and basins. (See Plate XIV.) The direction of dip is consequently very variable, but the general direction of strike is W.S.W.

The banding of these gneisses is one of their characteristic features. The individual bands are broader than those in the granulitic types, being often an inch or two in breadth. This structure is chiefly due to variations in the proportion of the dark constituents in the different layers, and to the presence of layers and lenticles of basic material. Most of the quartz occurs in parallel lenticles, or rods, connected at short intervals in such a way that on weathered faces it stands out as a complex network. It is opalescent and sometimes of a pale blue colour.

A very acid kind of augite-gneiss which occurs on the north side of Scourie Bay, about ¼-mile N.W. of Scourie House, is coarse grained, grey, and chiefly composed of quartz and felspar. Its pale green pyroxene is changed in places to aggregates of fibrous hornblende (4889). At Scourie Mor a considerable exposure of a somewhat different variety of pyroxene-gneiss may be seen. This rock, mainly composed of felspar, is dark grey in colour, with many reddish patches in which ferric oxide has been deposited along cracks in the quartz and felspar.

These gneisses enclose frequent lenticles and lumps entirely composed of hornblende or pyroxene. The bands of the gneiss partly end off against these masses and partly bend round them, as may be well seen near the top of a scar on the north side of the road at the south-east end of Loch a' Bhaid Daraich at Scourie. Many of the lenticles are banded, and their folia terminate abruptly at their margins against the enclosing rock, as shown near the west end of Loch na h-Airdh Sleibhe. A much larger basic mass is exposed about half a mile south of Cnoc Mhichie, where in one place the bands in the lenticle are cut by the pale gneiss, but in another lie parallel to those in the adjacent gneiss and to the junction line. In the last-named exposure the gneiss immediately surrounding the lenticle is more acid than that which lies further away—a feature suggestive perhaps of segregation from one magma, the darker ingredients having separated first. The banded structure may conceivably have arisen in consequence of a movement of the magma simultaneously with the segregation, when some portions of the basic material had become sufficiently solid to act as "eyes." The more liquid portions may have thinned out at the sides of the lenticles, or bent round them or cut across them. In some basic lenticles the bands near the ends rapidly diminish in breadth and combine to form streaks which may be traced long distances in the surrounding pale gneiss. These streaks run parallel to other bands in the gneiss and seem similar lithologically to many of them. A case of this kind is seen 300 yards north of Loch a' Bhaid Daraich.

In various places, for instance on the east side of Lochan an

Freagairt, gneisses with basic knots and confused banding are overlain or underlain by more even banded gneisses. In a section on the shore at Bagh Leathan, south of Duartbeg, a gneiss with basic lenticles is cut across diagonally near the top of the section by an overlying paler gneiss; several of the basic lenticles are cut by the overlying gneiss, and the rocks near the junction do not seem granulitic.

Lines of transgression or discordance are well seen in the area between Creag a' Mhail on the north side of Scourie Bay and the road on the south-east—an area in which the gneiss dips almost constantly north-west and cannot have been much altered since the intrusion of the dykes. Lines of discordance sometimes run in the direction of the general strike of the gneiss, at other times they cut it at considerable angles, but in either case they are unaccompanied by granulitisation, and differ thus from the thrusts that came after the intrusion of the dykes. The absence of granulitisation and of a distinct second foliation parallel to these lines of discordance perhaps indicates that these lines were caused by movements in the mass when in a viscous condition. This inference is supported by the fact that many of the lines, including some which cut the banding almost at right angles, are filled with streaks of opalescent quartz and felspar which are coarser in grain than the adjacent gneiss.

In a few places within the pyroxene-gneiss an acid rock occurs which presents but little indication of banding, and consists chiefly of rather coarse granules of opalescent quartz and white felspar. It resembles a fine-grained granite in which mica is scarce. An example of this type covers a considerable area on the south-west side of Creag a' Bhaid Daraich.

The Granular and Granulitic Hornblende-Gneisses.—The hornblende-gneisses proper, containing hornblende in compact forms, together with both quartz and felspar, and possessing a granular structure, accompany the granular biotite-gneisses and are often associated with them in subparallel layers. The proportions of hornblende and biotite vary greatly in different bands. No sharp distinction can be drawn between the hornblende-gneisses and the biotite-gneisses.

In the north-east belt the hornblende-gneisses are common and, as far as observed, all possess a granular structure. They may be studied in Fanigmore Bay, on the east side of Eilean Mhadaidh; in the river below Laxford bridge, and a quarter of a mile north-east of Airdachuilinn, Loch Stack. The hornblende in these rocks is generally fresh and black in hand-specimens: the granules of quartz and felspar are larger than in the granulitic-gneisses, and the quartz is never distinctly opalescent. Where the early banding is folded, a second foliation is often indicated by an elongation of the hornblende crystals, as may be seen near the east side of the path three-quarters of a mile slightly south-east of Loch Stack Lodge, and also 300 yards south-west of Laxford bridge.

In the middle belt, banded gneisses, in which the chief ferro-magnesian constituent seems to be hornblende, are seen at the following places:—a quarter of a mile S.S.W. of the outlet of Loch nan Breac, on the west side of Loch na Claise Fearna, on the south-east slope of Ben Stack, and on the north-east and east declivities of Ben Dreavie. It is uncertain to what extent the structure of these gneisses is granulitic, but it is known that hornblende gneisses with a granular structure extend as far south-west as Tarbat, three miles north of Scourie.

In the south-west belt, flaggy hornblende-gneisses are met with in which the quartz and felspar are thoroughly granulitic, but these are confined to the neighbourhood of the pre-Torridonian thrusts, and are commonly associated with the granulitic biotite-gneisses in areas which have been subjected to these movements. Granulitic hornblende gneiss occurs in a shear zone, running slightly north of west, on the coast a mile and 300 yards N.N.E. of Creag a' Mhail, near a thrust on the north-east side of Cnoc Odhar (three miles N.N.W. of Kylesku), and in one near the west end of Loch na h' Airdh Sleibhe (1¾ miles E.S.E. of Scourie). Many of the granulitic gneisses to the south and south-east of Scourie contain both hornblende and biotite, and the granulitic hornblende-gneisses merge imperceptibly into the granulitic biotite-gneisses.

Muscovite-Biotite-Gneisses.—In this district some of the gneisses, with biotite as their chief ferro-magnesian constituent contain also muscovite; other types occur in which muscovite is more abundant than, or even prevails to the exclusion of, biotite. Granulitic gneisses with predominating muscovite are seen half a mile south of Fiondail Bay, and by the path nearly ⅜-mile south-east of Ben Strome. The biotite-gneisses of the early complex usually contain streaks and lenticles of hornblende and biotite, which help to distinguish them from the later intrusive granite-gneisses. In the biotite gneisses the colour is generally pale grey, and the quartz granules are more elongated than in the granitic gneisses. On the other hand, the biotite gneisses of the fundamental complex are sometimes difficult to separate from those of the later granitic intrusions; indeed, it is possible that some of the streaks in the former may be due to *lit par lit* injection.

The biotite-gneisses proper chiefly occur in the north-east belt, where the later granite-gneisses and pegmatites are specially abundant, as, for example, on the coast W.S.W. of Badcall Quay, in the Laxford river ⅓ mile and half a mile above the foot of Allt an Rabhail, a tributary of the river Laxford, and in the little glen south-west of Badnabay. The section exposed in the last of these localities crosses the junction of the north-east and the middle belts, and notwithstanding the number of pegmatites and granite-gneisses, a gradual passage seems clearly traceable here between the two types of biotite-gneiss which respectively characterise these two areas. The average size of the granules of quartz and felspar in the early gneisses gradually increases down this burn in a north-east direction, and at the same time the quartz streaks become more clear and transparent. Specimens 3471, 3469, and 3472, all from this stream, have been examined under the micro scope: the first is classed as a biotite-gneiss proper, while in the

Fragment of banded and contorted Hornblende-Gneiss, enclosed in foliated pegmatitic Gneiss.
Ard Shieldaig, Loch Torridon, Ross-shire.

other two, obtained from higher up the section, the structure is partly granulitic, thus resembling all the biotite-gneisses from the middle belt which have been examined.

In the north-east belt second foliation has not been observed so often as in the middle belt, and the planes of this foliation are there not generally very close.

In the middle belt the biotite-gneisses are not always so thoroughly granulitic as those near many of the thrusts in the south-west belt. They are found at many places in the tract which extends from the coast near Acarseid Mhic Mhurchaidh Oig and Rudh' an Tiompain to Lochan an Fheidh, south-west of Loch Laxford; also on the east side of Clar Loch Mor, the south-east side of Loch na Mnatha, the east side of Loch Eileanach, and on Meall nam Breac—all south-east of Scourie. It is worthy of note that the bands of gneiss are frequently thinner and the component granules of quartz and felspar are usually smaller in the limbs of sharp folds than near the axes. Indeed, near the south-east side of Loch na Adh this attenuation is so marked that the thickness of individual bands is six times less in the limb than near the axes.

The biotite-gneisses of the early complex in the south-west belt which have been examined under the microscope are classed partly with those in which the biotite is in aggregates of small scales and partly with those in which the structure is granulitic. The granulitic gneisses occur along the thrusts near which the basic dykes have been converted into hornblende-schist. The gneisses with aggregates of small scales of biotite, on the other hand, have no close connection with, and sometimes occur far away from, these lines of disruption: they appear to be altered forms of pyroxene-gneisses and have been described with them. Granulitic biotite-gneiss is perhaps the commonest rock near the thrusts in the south-west belt, where it forms bands, with subordinate granulitic hornblende-gneiss and hornblende-schist, which are sometimes more than 100 yards wide. Some of the bands of granulitic gneiss are bounded by distinct lines of fracture, but more generally their sides are ill-defined, the intensity of the folds and the degree of alteration gradually decreasing as we recede from their centres.

FIG. 3 ($\frac{1}{24}$). — Folded banded gneiss showing thinning of the long limb and second foliation parallel to the axial planes of fold. South side of Loch na h-Adh, three miles west of Loch Stack.

The granulitic gneisses usually weather with smoother outlines than the contiguous gneisses of the fundamental complex, and sometimes form lines of depression or the under parts of scars, which can be traced for long distances. Examples of these topographical features are seen on the east side of Cnoc na Glaic

Moire (two miles E.N.E. of Scourie), the north side of Ben Auskaird (four miles N.N.W. of Ben Auskaird), and on Cnoc Mhichie, one and a half miles N.N.E. of Scourie. Most of the granulitic gneisses contain a larger proportion of mica than the adjacent less altered gneisses; indeed, the greater part of their mica must be of secondary origin, derived from minerals that occur in the other gneisses. As already indicated, the less altered gneisses near most of the pre-Torridonian thrusts are chiefly those with pyroxene or with aggregates of hornblende and biotite, which have probably replaced the pyroxene, and from these most of the granulitic biotite gneisses have evidently been derived. The biotite must have been chiefly formed from pyroxene or hornblende, and the white mica from felspar. The secondary origin of the micas is often evident from their arrangement along later foliation planes. The amount of pyroxene, or of pyroxene and hornblende, varies considerably in different bands of the less altered gneiss, and so, too, does the amount of biotite in different bands of the granulitic gneiss. The thicker streaks of biotite in the granulitic gneiss perhaps represent dark hornblendic streaks which have been converted entirely into biotite.

The minerals on the foliation planes of the granulitic gneisses are often arranged with their long axes parallel. The direction of elongation, or stretching, varies in different localities, but near the same thrust it is generally persistent for long distances. Over the greater part of the district, when the observer looks north towards the foliation planes, the lines of elongation appear diagonal, about half way between the directions of strike and dip of the planes, and with their lower ends on his right hand.

Near the north-west side of the lower half of Loch an Leathaid Bhuain (north of Loch Glendhu) a pale grey or pink gneiss is extensively exposed. It has a massive character, strikes nearly east and west, and contains both biotite and hornblende, but in feeble quantity. Its foliation is often indistinct, but generally parallel to the boundaries of the rock. Similar gneisses spread over a considerable area between a quarter of a mile north-west and $\frac{2}{3}$-mile north of Ben Strome (two miles N.N.E. of Kylesku).

BASIC DYKES.

The basic intrusions of pre-Torridonian age in this district nearly always appear in the form of dykes, many of which can be traced in straight lines for miles. Their general direction is north-west or between north-west and W.N.W., save where deflected by later movements.

Sometimes two dykes unite, thereby forming a broader intrusion; sometimes those of larger size give off branches which either end abruptly or rejoin the parent dyke within a short distance. Others split into thin strings or follow the planes of original banding of the contiguous gneiss, at low angles, like sills. An example of this last feature occurs about 700 yards north-east and three-quarters of a mile E.N.E. of Glencoul House. Yet again a dyke may be seen to taper off and disappear, while another, or perhaps the same intrusion, may begin not far off, and follow a parallel course, as, for instance, on the shore west of Scourie More, on a small peninsula named Cleib Mhor. In a few places, one dyke can be observed to cross another of much the same composition—a feature displayed in the peninsula west of Badcall, and between 100 and 200 yards south-east of Lochain Bealach an Eilein (one mile north of Scourie). Finally, some dykes run in groups across the gneiss-plateau, as between the shore south of Badcall Bay and the Cambrian escarpment north of Loch Glendhu —a distance of seven miles.

The breadth of some dykes is remarkable. The example which appears ⅓-mile north-east of Loch an Leathaid Bhuain measures 140 yards across—perhaps the broadest instance in this area. Others are about 100 yards in width. In the lines of pre-Torridonian thrust and contortion the average breadth of the dykes is much smaller than in the less altered areas; some which in these areas measured 40 yards across have been deflected as they approach the shear-zones, changed into hornblende-schist, and attenuated to a few feet. In the middle belt, a great part of each dyke has taken the form of hornblende-schist, and its original thickness has probably been diminished by the contortions to which the rocks have there been subjected. These contortions are, however, not so intense as those near most of the thrust lines in the south-west belt.

In the case of the broad dykes the margin is finer grained than the interior, and resembles that of the thin intrusions. No vesicular cavities or amygdules have been detected.

The intrusive character of the dykes in the tract south of Scourie is very apparent, as the majority of them cross the foliation of the gneiss nearly at right angles. An excellent example of an intrusive junction is displayed by the dyke about a quarter of a mile south-west of the east end of Loch a' Bhaid Daraich, Scourie —one of those which supplied Dr. Teall with proofs of the alteration of a massive basic rock into hornblende-schist. (See Plate XX.)

The shore north-west of Badcall shows a dyke which seems to have nearly reached its upward limit of protrusion, at what is now the surface of the ground. Rather more than half a mile W.S.W. from Cnoc na Bainneire, two small dykes run in a north-west direction and approach the sea-coast. The more westerly one ends off upward, being plainly overlain for a short distance by the gneiss, beyond which it reappears at the surface on the same line.

Regarding the surface features produced by these intrusions, it is observable that many of the undeformed dykes frequently make ridges and crags; others nearly always give rise to hollows and show few rock exposures. It is to be remarked, however, that the same unfoliated dyke may form a ridge at one part of its course and a hollow at another, though no important differences may be observable either in the characters of the intrusion or of the contiguous gneiss. (See Plate XIX.)

South of Scourie nearly all the dykes are massive epidiorites, comparatively few having been converted into hornblende-schist throughout their whole breadth. Other interesting types appear to the north of that village. Thus, in one of the least altered portions of the Fanigmore dyke, south-west of Loch Laxford, the plagioclase and pyroxene are related to one another as in many unaltered igneous rocks. Nevertheless a considerable quantity of biotite is here intimately intergrown with the pyroxene. This type may be termed hyperite, as it contains apparently a little enstatite, as well as augite. About half a mile north-west of Cnoc an Fhir Bhreige, the Fanigmore dyke is cut by another of the common type. Again, south-east of Loch Bad an t—Seasgaich, which lies to the south-east of Loch na h' Airdh Sleibhe, two dykes of coarse rock, containing large crystals of felspar, have not been much foliated, but they show abundant large plates of yellow mica on certain planes. They weather with a bluish-black colour, and remind one of the Fanigmore dyke. The adjacent dykes are of a different type, being fine grained and well foliated, but there is no evidence to prove their age with respect to the coarse dykes. The dykes, which have been deflected along thrusts for great distances out of their usual course, are generally finely foliated. The one running nearly east and west for more than a mile along the east part of the Ben Strome Thrust, and that which can be traced for nearly a mile from the coast, half a mile N.N.E. of Creag a' Mhail, are both unusually finely foliated, and contain abundant flakes of biotite on their foliation planes. In the first-named, the biotite is clearly of secondary origin, for that mineral does not occur in the less-altered portions of the dyke. Most of the other dykes in which biotite is conspicuous are also unusually finely foliated.

Another peculiar type—a biotite hornblende-dolerite—which contains biotite even when it shows little or no foliation, has been traced from near the north-west end of Loch a' Bhaid Daraich, Scourie, to a place about one-third mile slightly east of south of the top of Cnoc Mhichie, and thence to the north end of Loch na Mnatha. This example differs from the dykes near it, in its greater proportion of felspar and in its mode of weathering. Between Loch a' Bhaid Daraich and Cnoc Mhichie—a distance of about a mile—its general direction is N.N.E., nearly at right angles to the normal course of these intrusions; between Cnoc Mhichie and Loch na Mnatha its trend differs less from that of the other dykes. The evidence in the field renders it probable that it is older than the other dyke-intrusions in the neighbourhood.

In some dykes there is an original broad banding which is crossed by, and must be older than the fine foliation. In the broad dyke two-thirds of a mile slightly north of west of the outlet of Loch na h-Adh there are alternating pale and dark bands which are rather more steeply inclined than the fine foliation planes.

The hornblende in the dykes is never in prominent "augen" forms, but usually occurs in small needle-like prisms lying on the foliation planes and parallel to the direction of stretching. The prisms are, as a rule, less stout than those in the early basic rocks. In the dyke at the head of the glen south-west of Badnabay and the one running north-west from the north end of Loch na Gualainne—both of them near the area in which the granite gneisses are abundant—the hornblende is, in places, in rather stouter forms than usual.

Garnets have hardly ever been observed in the dykes, save in some instances near the north-east side of the middle belt. They are smaller and less numerous, but generally display more idiomorphism than those in the early basic rocks, and they have no rims of felspar like those in the latter group.

At the close of the present chapter fuller reference will be made to the pre-Torridonian lines of movement in this district (whereby new structures have been developed both in the dykes and gneiss), and also to the flinty crush-lines. Brief allusion may, however, be made here to certain points. In the sheared dykes, lenticles of unfoliated, or slightly foliated, rock are common, resembling "augen" structure on a large scale, as shown on the north-east side of Aird da Loch, near the foot of Loch a' Mhuirt (two and a half miles east of Scourie), about 700 yards north-east of Cnoc Mhichie, and a quarter of a mile south of the south end of Loch nam Breac. Again, in some dykes black flinty strings, that might be mistaken for tachylite, are exposed at various localities. They may be seen on the south side of the large irregular intrusion between the shear-lines half a mile south of Ben Strome, and in the broad dyke three-quarters of a mile S.S.E. of Loch Poll an Achaidh. A dyke crossing the Scourie road 250 yards north of Duartmore bridge is also fringed with a narrow band of black flinty rock, and the crushed rock in the thrust, 350 yards south of Loch Allt nan Ramh (one mile south-east of Duartmore bridge), is crossed by fine-grained splintery strings.

Reference may be made to the apparent absence of basic dykes in the north-east belt adjoining Loch Laxford and Loch Stack. They possibly occur there also, but may have escaped recognition owing partly to the veins of pegmatite and granite-gneiss which traverse them, and partly to changes in lithological character induced by these acid intrusions. Such metamorphism resulting from the injection of granite and pegmatite may have led to a recrystallisation of both the early basic materials and the basic dykes into much the same types of rock. As already indicated, some slight evidence may be adduced to show that the foliated basic dykes change their character as the area of granite gneisses is approached, and hence still more marked changes might be expected within the granite gneiss belt. It is possible that thrusts exist in the north-east belt, though they have not been recognised.

In the area affected by the post-Cambrian thrusts, the most north-easterly basic intrusions that have been recognised run from a little south of Lochan Feith an Leothaid in a W.N.W. direction north of Glencoul river. South-west of Loch Beag, at the head of Loch Glencoul, basic dykes are numerous, and as far north-west as the margin of the Cambrian quartzite on Glas Bheinn. It seems probable that in the displaced gneiss north of that hill and between Loch Gainmhich and the Lochan a' Choire Ghuirm, dykes have been sharply folded on an extensive scale, so as to cause the same dyke to be represented by several more or less parallel outcrops. The outcrop of the broad dyke, which runs north-west from near the north end of Lochan a' Choire Ghuirm is such as might be produced by a repetition of folds with axial planes striking north-west. These supposed folds seem independent of the post-Cambrian movements, though they affect rocks which have also been displaced by the Glencoul thrust.

Ultra-Basic Dykes.—In this district only a few dykes of ultra-basic composition have been noticed. The best example is a picrite which occurs near Geisgeil, about two and a half miles south of Scourie. It is about 20 yards in width, and may be followed south-east for more than a mile, in or uear the burn called Allt Crom Geisgeil, Narrow dyke intrusions like peridotite are exposed at the following localities: about 350 yards south-east of the east end of Loch na h-Airdh Sleibhe, north-west of Loch Crocach (one mile north of Duartmore Bridge), between the Ordnance Station 794 and the large dyke north-east of it, and about 30 yards to the south-west of the latter locality.

Dykes which seem to consist chiefly of small needles of hornblende, and which generally form trench-like depressions, occur half a mile south of Loch na h-Adh (three miles west of Loch Stack), and a mile and a quarter E.S.E. of Ben Auskaird. The rock at the latter place is unfoliated, and its course is more nearly east and west than that of the basic dykes.

Microcline-Mica Dykes.—The microline-mica dykes occur in the neighbourhood of Kylestrome and Aird da Loch (between Lochs Glendhu and Glencoul). Where least deformed and unaltered, the rock of which they consist is of purple-brown colour, and shows faces, sometimes half an inch broad, of red felspar containing many inclusions of dark mica. Indeed, felspar forms a considerable proportion of the whole mass, and in the thin slices 3242 and 2734 it presents microcline structure. The rock is often much decomposed and weathers with an ochreous surface. The direction of some of the least altered of these dykes is north-east, but one of them runs north and south. In one case, to the west of the post-Cambrian thrusts, there are traces of foliation, which may be assumed to indicate that the dyke possessing this structure is of pre-Torridon age. Another dyke which seems to cross several basic dykes runs in a south-westerly direction from the south shore of Loch Glendhu (where it is about six feet thick and shows no distinct foliation), through Aird da Loch, to Loch Glencoul, and is accompanied by a fault that displaces the basic dykes. About 80 yards further east near Loch Glendhu, on the face of a crag called in the six-inch maps "Creag an Tombaca," various thin, vertical strips of dark micaceous schist, from two to six inches thick, cut the gneiss and run nearly east and west. They probably represent finely foliated portions of the six-feet dyke, which have been twisted and altered along an east and west thrust. Their foliation planes have a general direction parallel to the sides, but they are considerably bent in places. Under the microscope the structure is seen to be that of a typical crystalline schist.

Another microcline-mica dyke, which is vertical, about four feet thick, and traceable for 60 yards in a north and south direction, occurs near the south side of the path half a mile N.E. of Kylestrome. At the road it is deflected westwards by one of the pre-Torridonian thrusts. A specimen of this rock, analysed by Mr Barrow, gave the following result:—

SiO_2 - -	57·30
TiO_2, Al_2O_3, P_2O_5 - -	17·13
Fe_2O_3 - -	5·31
CaO - -	4·25
MgO - -	4·44
K_2O - -	9·05
$Na\ O$ - -	·40
Loss on ignition -	·53
	98·41

The total iron is reckoned as Fe_2O_3.

THE LATER GRANITE GNEISSES.

As already indicated, intrusions of granite-gneiss, later than the basic dykes, are extremely abundant in the north-east belt of the district. This belt gradually increases in breadth in an E.S.E. direction towards the scar of Cambrian quartzite. While near the entrance to Loch Laxford it is about half a mile broad, near Loch Stack it widens out to about a mile and a half; indeed, it is probable that the granite-gneisses continue to increase in development in an E.S.E. direction under the Cambrian rocks, for the thrust granite-gneiss between Loch More and Loch na Creige Duibhe is much wider than any single band of this rock west of the post-Cambrian displacements. Most of these gneisses take the form of sills, but some of them occur as dykes which strike more nearly E. and W. than the neighbouring rocks. The intrusions of gneiss gradually disappear south-westwards; in the south-west belt a few thin bands may possibly belong to the same series.

The south-west limit of the area in which the granite-gneisses are specially abundant is defined by a broad sill, or series of sills, passing rather more than 400 yards north-west of Loch na Seilge, near Loch Stack (Sheet 107). This boundary is not, however, very definite, for a close set of parallel sills runs for a little distance on either side of the line taken on the map. The inclusions of older gneiss in this Loch na Seilge sill become more numerous north-westwards from Badnabay, until they finally surpass in bulk the granitic-gneisses associated with them. On the south side of Loch Bad an t-Seabhaig (three-quarters of a mile S.S.W. of Laxford Bridge), the sill dips on the average 45° or 50°, and the outcrop is about a third of a mile wide. North-eastwards for about a quarter of a mile, the earlier gneisses alternate with thin bands of granite-gneiss and pegmatite, followed by another broad sill which, near Loch Bad an t-Seabhaig, dips at about 50° and has a width of about 250 yards, which decreases towards W.N.W., and increases in the opposite direction.

Many of the sills are so nearly parallel to the bands of gneiss of the fundamental complex that evidence of their intrusion is not readily obtained. Their intrusive nature, however, is well seen on the hill one-third mile S.E. of Loch Bad an t-Seabhaig. The dyke at the road 40 yards south of Laxford Bridge, and the two on the south-west side of Loch Stack, a little south-west of the great sills, are unusually long and straight. The first continues for at least a mile and a quarter in a W.N.W. direction, and is from 15 to 35 feet wide. The sills at Rudha Ruadh and Loch na Seilge generally form lower and less craggy ground than the earlier gneisses. Their rock-exposures weather with rounded outlines, and are frequently crossed with gently-inclined parallel joints, which are in many localities nearly at right angles to the foliation. On the north-east side of Loch Stack, about a mile from the Lodge, both the granite-gneisses and the others are crossed by strong vertical joints striking about 18° east of north.

Most of the granite-gneisses are of a pale pink colour and contain many grains of felspar, often from 1-20 to 1-10 inch in breadth, which have either a red colour or a pale-bluish chatoyant lustre. In thin slices many of the grains show microcline structure, but oligoclase is also abundant. In many of the thin bands and dykes, the felspar when fresh is almost colourless and the rock is pale-gray. The quartz grains, generally distinct on the weathered faces, sometimes, particularly near the outsides, have a reddish colour, and contain small inclusions of hæmatite. Many of the quartz streaks are distinctly elongated along the foliation planes, but the foliation is chiefly marked by the distribution of the dark ferro-magnesian constituents, of which biotite is generally the most abundant, appearing in small parallel flakes. Hornblende also is seen in abundance in the massive sills in the following places: Rudha Ruadh (a promontory at the mouth of Loch Laxford); half a mile S.S.W. of Laxford Bridge; a third of a mile E.S.E. of Loch Bad an t-Seabhaig; the north-east side of Loch Stack; and a third of a mile E.N.E. of Airdachuilinn. White mica rarely appears in the thick sills.

Dyke in Gneiss, Creag a' Mhail, Scourie. The notch in distant promontory, the small bay in middle distance, and notch in foreground, are due to the dyke.

The granitic gneisses are seldom, if ever, thoroughly granulitic, but a mylonised structure, accompanied with some granulitisation, is common among them. Cataclastic action has affected the gneiss after it was already foliated, as will be referred to subsequently*. A few thoroughly granulitic dykes occur within the south-west belt, and possibly represent intrusions of the same age as the granite-gneisses.

The Rudha Ruadh sill sometimes assumes a banded structure, from the occurrence of dark stripes which contain hornblende in more abundance than the rest of the rock. Such stripes are seen in the following localities: a third of a mile slightly east of north of Cnoc an Fhir Bhreige (south-west side of Loch Laxford), about 700 yards E.S.E. of Badnabay, near Allt na Suileig (about one mile S.S.E. of Laxford Bridge), and on the north-east side of Loch Stack, two-thirds of a mile from the Lodge. In the Loch na Seilge sill a banded structure has been noted in one place, about a third of a mile S.S.E. of the outlet of Loch Bad an t-Seabhaig.

The gneiss composing the broad intrusions is generally coarser than that in the thin sills and dykes, but in some localities within the former, and running generally parallel to their margins, some bands occur which are much finer in grain than the rest. Perhaps the latter differ in age from the others.

Broad bands of pegmatite are common in the massive intrusions. Thin pegmatites, from a quarter of an inch to six inches thick, are also abundant, running for the most part parallel to the foliation, and only an inch or two apart; on weathered surfaces they usually project slightly above the rest of the rock, and are of a paler colour. Some of the granite dykes never seem to be crossed by broad pegmatites, and it is probable, as will shortly be shown, that they are of later age.

Throughout this district the granitic rocks, excluding the pegmatites, are never free from foliation, which in the sills, in some of the dykes, and in most of the irregularly-shaped masses, is parallel either to the broad bands in the earlier gneiss, or to a second foliation which crosses these bands.

In certain dykes the foliation is parallel to the sides, and a parallel second foliation is sometimes visible in the earlier gneisses. Where the latter has not been developed, it is probable that the dykes may have formed lines of weakness along which movements proceeded without having much effect on the surrounding gneiss. Dykes, foliated parallel to the sides, may be seen in the headland E.S.E. of Eilean Port a' Choit (at the head of Loch Laxford), and half a mile north of Badcall Quay.

About 50 yards south of the south-east end of Loch a' Cham Altain (1 mile north-east of Loch Stack Lodge) a fine-grained granite-gneiss appears which sometimes behaves as a sill and sometimes as a dyke. The sill portion is for the most part foliated parallel to its side, but in one place where both the gneissose

* See sec. on pre-Torridonian movements, page 152.

granite and the earlier gneiss are bent and make an angle of 30° with their usual direction, there is a departure from this rule. At the bend the foliation in the granite-gneiss is not deflected but continues its normal direction, appearing as second foliation planes in the gneiss of the fundamental complex .

Thin bands of granite-gneiss are not uncommon in the basic dykes in the north-east part of the middle belt. They are met with, for example, in the broad dyke at the north-east side of Loch na Claise Fearna (one and a half miles W.S.W. of Laxford Bridge); a quarter of a mile east of the outlet of Loch an t-Seana Phuill; and rather more than half a mile W.N.W. of Loch na Seilge (one and a half miles west of Loch Stack Lodge). At each of these localities the foliation in the granitic intrusion is in the same direction, and about as well marked as that in the basic rock. In the last-mentioned locality the foliation planes make an angle with the sides of the granitic band, and can be traced from the one rock into the other.

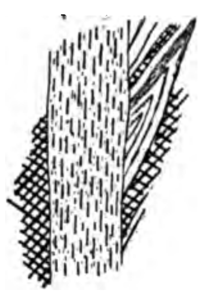


FIG. 4 ($\frac{1}{240}$).—Dyke of granite-gneiss with pegmatite rods cutting folded gneiss and coarse pegmatite (cross hatched). About a mile slightly south of east of Loch Stack Lodge. The dyke is foliated parallel to its side. The pegmatite shows no appreciable foliation.

All the granite-gneisses are not quite of the same age. Near the top of a scar 100 yards from Loch Stack, and rather more than three-quarters of a mile slightly west of north of Airdachulinn, a fine-grained granite-gneiss with short pegmatitic streaks overlies and apparently truncates a coarse granite-gneiss in which no such streaks occur: it seems also to truncate a nearly vertical pegmatite in the coarse rock. Another example occurs north-east of the terrace nearly a mile slightly south of east of Loch Stack Lodge, where a dyke of fine red foliated granite with thin parallel pegmatite streaks comes in contact with a sill of coarse granite-gneiss containing some thick pegmatites. The line of junction, visible for eight or nine yards, is approximately straight, and the foliation, both in the dyke and the sill, is in the same direction, and makes a small angle with the junction.

In the area west of the post-Cambrian thrusts the granite-gneisses which occur furthest south-west, and which we can with confidence claim as part of the same series as the Laxford granite intrusions, are seen in the following places: near the south side of Loch a' Mhuirt, a third of a mile from the foot, a third of a mile south, and two-thirds of a mile S.S.E., of the outlet of Gorm Loch, east of Scourie.

Other thin dykes, which may possibly belong to the same set of intrusions, but are now in a thoroughly granulitic condition, occur still further south-west in the following places: 70 yards off the north end of Loch an Laig Aird (one and a half miles north-east of Scourie, 200 yards west of Meall nam Breac, near the south side of Loch na Craoibhe Moire (three miles E.S.E. of Scourie), and near the east end of Loch a' Bhaid Daraich. The dyke in the last locality can be traced in a north-east direction for half a mile.

Pegmatites.

Most of the coarse pegmatites are not foliated, which is perhaps due to their coarse grain, the plates of felspar and the quartz streaks being often several inches across. These veins are not all of the same age, for one is often cut by another, and the granite-gneisses which cut some pegmatites may in turn be cut by others. Some of the unfoliated pegmatites are cut by foliated granitic bands, and it is certain that the production of foliation had not ceased at the time these veins were produced. Pegmatites with graphic structure have been noticed in many places. Flakes of black biotite are tolerably abundant and sometimes large, as, for instance, in a graphic pegmatite two-thirds of a mile N.N.E. of the outlet of Loch an Leathaid Bhuain, where they are six or seven inches across. Grains and patches of some black iron ore, probably ilmenite, are common.

In the area west of the post-Cambrian thrusts pegmatites of the usual type, and several yards wide, cross, or occur within, foliated basic dykes, a quarter of a mile west of Loch na Seilge (west of Loch Stack Lodge) and a third of a mile west of Cnoc Bad na h'Achlaise.

Pegmatites are numerous in the N.E. belt of the district, where they are often several yards broad, and where, as already indicated, the granite-gneisses are most abundant. Many of them behave like sills for short distances, but their sides are rarely straight or sufficiently regular to be easily mapped. They decrease in number in a south-west direction, but even in the south-west belt broad examples occasionally occur. One conspicuous vein may be seen on the shore west of Scourie More, and east of Dubh Sgeirran, and another occurs near the road about 300 yards north-east of the Scourie Free Church.

Fig. 5 ($\frac{1}{10}$). — Nearly horizontal pegmatite cutting nearly vertical banded gneiss. South side of Loch Eileanach. The pegmatite is banded parallel to its sides, but is crossed by a foliation parallel to the (modified) gneiss banding.

Peculiar pegmatitic lumps, mostly varying in size from one to three inches across, and thin irregular streaks of similar material are often observable in, or at the sides of, bands of biotite-hornblende-rock. In the specimens of these pegmatites which have been examined the only felspar present is albite or an acid oligoclase. A thin pale-grey nearly horizontal pegmatite, only an inch thick, which displays an arrangement in layers parallel to the side and also a foliation crossing the margins, was noticed about 300 yards south of the west end of Loch Eileanach (two miles south-west of Loch Stack Lodge). Its outer layers are much finer in grain than those of the interior, and in both, the quartz streaks are arranged almost at right angles to the sides and parallel to the broad bands in the gneiss.

Among the Lewisian gneisses, reappearing above the Glencoul thrust plane, between Loch na Creige Duibhe and the Loch Beag of Glencoul, pegmatites occur in abundance, some of which cross foliated basic dykes.

About 140 yards W.N.W. of the top of Ben Stack, and nearly 200 yards from an outlier of Cambrian quartzite, the felspar in a pegmatite has been partly converted into agalmatolite.

Pre-Torridonian Movements.

The important lines of thrust and folding which took place before the deposition of the Torridonian strata, and by which such a profound modification of structure has been induced in the basic dykes and gneisses, are well developed in this area. In the tract which lies to the south of Scourie two main directions of these movements are observable, one trending about north-west and south-east and the other nearly east and west. The lines of disruption which run towards north-west, roughly parallel to the direction of the principal basic dykes, and often coincident with them for long distances, are perhaps the earlier of the two series. A marked example of them occurs in the large dyke between Scourie and Scourie More, which usually consists of a massive rock 50 yards in width. South of the Scourie road, however, it has been converted into a thin band of hornblende-schist, only a few yards wide, by a movement-line nearly parallel to the course of the dyke. Occasionally the north-westerly shear-lines are unconnected with dykes. The east and west lines of movement, however, are the most prominent. Most of them, as they approach the coast, incline more to the south of west, so that the direction becomes 20° or 30° south of west. An excellent instance may be traced inland for two miles from Duartbeg, about a mile south of Badcall Bay. The dykes on the north side of tnis thrust are apparently shifted at least a mile to the westward of their usual course. Other examples of displacement of the basic dykes occur in the area south of Loch na h-Airdh Sleibhe (one and three-quarter miles E.S.E. of Scourie), where the movement-lines run east and west, and are particularly numerous on the east side of Loch Bad nam Mult. They are not always straight nor of the same width; occasionally they branch and again unite, thus enclosing lenticular pieces of still granular gneiss. The large shear-zone north-east of Loch na Beiste Brice (three and a half miles S.S.E. of Scourie), which is about 130 yards in width and includes a band of limestone, splits up to the eastward into a great number of minor lines of movement, most of which die out or become unimportant, while its north and south margins continue as two great lines of disruption about 200 yards apart. The limestone just referred to is a lenticular mass tapering off both in an E.N.E. and W.S.W. direction, its length being about a quarter of a mile and its greatest breadth 25 yards. Like all the adjacent sheared material, it is vertical. Two specimens of this rock have been examined microscopically. One (4646) is a coarse-grained somewhat brownish aggregate of grains of ferriferous carbonate, together with some chlorite and a colourless mica. Another specimen (4894) is a coarse-grained foliated rock largely composed of calcite, biotite, and hornblende, with epidote as an accessory.

Much vein-quartz has been developed in places along these movement-lines. A fine example of this is shown in Plate XXIII., which represents a part of the shear zone near the north end of Loch na Coille, about three miles and a quarter south of Scourie. In some places the veins are themselves schistose parallel to their sides.

From the south slope of Ben Dreavie to near Ben Strome, a considerable tract, nearly two miles broad, is almost free from such thrusts. The two lines of disruption which bound it gradually approach each other westwards, until the breadth of less altered gneiss between them on the sea coast is only about a quarter of a mile. The thrusts seem not unfrequently to die out in an east or north-east direction: there are, for instance, many sheared bands on the coast at and near Creag a' Mhail, Scourie, which cannot be followed half a mile inland.

In most districts the thrusts and limbs of fold near them are nearly vertical. In the south part of the south-west belt they sometimes hade to north—a remarkable feature in view of the S.S.W. inclination of nearly all the axial planes of fold in the middle and north-east belts. About 300 yards south-east of Loch Dubh a' Chnoic Ghairbh (one and a quarter miles north-west of Kylesku), a thrust in some places dips north-west at 30° degrees, and in other places is nearly horizontal.

Along many thrusts, the dykes are broken into wedges, the sides of which represent crush-lines, so that the intrusive character of the rock is no longer apparent. In the thrust on the north side of Loch a' Ghille Ruaidh (one mile north of Kylesku), at least four dyke stripes may be seen near the north-east end of the loch. As the broken or ruptured rocks are often finely sheared, it is probable that the ruptures took place towards the close of the movements. In other cases the evidences of rupture are less pronounced, and the zones of alteration perhaps represent merely areas of sharp contortion. From the prevalence of foliation in the dykes in the middle belt, even where no ruptures have been detected, it is inferred that foliation may often have been induced in dykes in consequence of folding. In the granulitic bands in the south-west belt the foliation in some of the dykes may also have been first set up during a period of folding.

It seems probable that in places where groups of close folds traverse vertical dykes which originally ran diagonally to the strike of the axes of plication, the course of each dyke has been bent, so as to make a less angle with these axes. If we take a sheet of paper and draw parallel black lines on it to represent dykes running in a north-west direction, and then fold the middle strip of the sheet into small folds with axes striking east and west, it will be seen, that, (1) the effect of the plication is to deflect the direction of the dykes and bring it nearer to east and west, (2) the changed paths of the dykes run in a westerly—not easterly—direction from their prolongations on the south side, (3) the dykes are diminished in breadth in the folded area in proportion to the closeness of the folds.

As a general rule the dykes are shifted westward on the north side of the thrusts, which is what might be expected, even if no actual rupture had occurred. A mile and a third E.S.E. of the top of Ben Auskaird, the gradual bending, thinning, and production of foliation in a broad dyke near a line of disruption can be clearly seen. About 20 to 30 yards on either side of the thrust, the dyke averages 50 yards in width, but in the deflected portions it is only three or four feet. Indeed, for a distance of 160 yards within the shear zone, no dyke-rock can be seen, but red crush-strings appear in the granulitic gneisses, striking parallel to the axes of folding. Further west, three-quarters of a mile south of Ben Auskaird, the evidence for the gradual bending of this dyke on the north side of the disruption is less satisfactory, and the rupture there is probably greater.

It is important to note that in those cases where dykes have apparently been driven westward, on the north side of a thrust, the lines of stretching or elongation of minerals, both in the foliated dykes and granulitic gneisses, are generally diagonal, with their lower ends on the observer's right hand as he faces the north. On the other hand, in those rarer cases, where the dykes have been shifted eastward, the lines of stretching are generally diagonal, with their lower ends on the observer's left hand as he faces the north. These latter phenomena are seen in the most southerly of the thrusts which affect the broad dyke in Creag a' Mhail, north of Scourie Bay, about 160 yards east of the west point of the Creag, and more clearly close to, and about 350 yards north west of, the north-west end of Lochain Bealach an Eilein. In some thrusts, the dykes show no lateral displacement but are cut into stripes separated by granulitic gneisses, and with their long axes parallel to the plane of disruption, an example of which is seen about 700 yards east of Cnoc na Glaice Moire (two miles E.N.E. of Scourie).

A further feature connected with the movements which have taken place along the lines of the dykes is well displayed by some examples in this district, where the gneisses next to the intrusive rock have been involved in the changes of dip and structure. Thus, in the case of the dyke which occurs at Creag a' Mhail, near Scourie, Mr Teall has noted that "the original character of the junction has been to a certain extent modified by subsequent movement more or less parallel with the margin of the dyke. This is indicated by the curving upward of the folia of the gneiss and by a change in structure from granitic to granulitic, as represented in Plate XXI. At the point where the photograph reproduced in this Plate was taken, a zone of disturbance crosses the dyke obliquely, and can be followed into the gneiss. Its course is indicated by quartz-veins, and the conversion of the massive rock of the dyke (which is here an epidiorite) into a hornblende-schist. The surrounding or 'country' rock is a biotite-gneiss."

As they approach the thrusts the less-altered gneisses may often be observed gradually to change their strike and dip, so as to become parallel, or almost parallel, to the strike of the contiguous granulitic bands, while, coincident with the alteration in strike, changes in lithological structure gradually appear. The gneiss is usually sharply folded along axial planes parallel to the strike of the granulitic bands. In this plicated zone the old broad bands in the gneiss are considerably thinned and modified in structure, but they can often be recognised, especially near the axes of fold, where there has been less drag than in the limbs. Parallel to the axial planes of folia, or sometimes parallel to an adjacent line of rupture, a second foliation is set up which obscures the early banding. But in places where there has been a distinct banding in the gneiss before the movements began, that banding is not wholly destroyed, except in the lines of rupture which occur within, or at the sides of, the folded areas. In some places the modified old banding is parallel to the second foliation, and also to various lines of rupture, and, in such cases, it is uncertain whether some streaks represent lines of rupture or old bands with a greatly-modified structure. But it is rare to find exposures more than a few yards wide wherein the old banding cannot be recognised. The foliation in most parts of the granulitic gneisses represents an old banding which existed before these gneisses acquired their granulitic structure, just as the banding in schist of sedimentary origin represents an old banding (bedding). The old bands have, however, in both cases been intensely altered in physical arrangement and lithological structure.

The apparent amount of the displacement of dykes along the same line of disruption varies considerably, as shown in the case of the Ben Strome thrust. From half a mile E.N.E. of the top of Ben Strome, north of Loch Glendhu, a thin finely schistose dyke runs in an east or slightly north of east direction along the line of movement. Further west, the predominant materials in this thrust are flinty crush rocks, some of which seem to have been made out of the gneiss and others from the basic dykes. The apparent amount of displacement of this schistose dyke cannot there be less than a mile and a quarter. Again, a little N.N.E. of Loch Allt nan Ramh (one and three-quarter miles N.N.W. of Kylesku) the apparent displacement along the same thrust is not more than a third of a mile. Nearly three-quarters of a mile slightly west of north of the outlet of the same loch it is not appreciable, but by Loch Eucail it again becomes considerable.

Some of the phenomena seen along this Ben Strome thrust recall those observed in parts of Argyleshire, where groups of parallel basalt dykes approach older planes of disruption. The dykes follow these crush lines often for considerable distances with diminished thickness. They have also been affected by renewed movements along the same lines of weakness, but they have never been converted into schists or into flinty rocks like the pre-Torridonian dykes. The difficulty of explaining the variation in the displacement of dykes would be lessened, if we might suppose that a line of weakness already existed along the thrust, before the intrusion of the dykes, and that certain dykes followed this path for varying distances. The movements that followed might efface the evidence of such an early line of weakness. If such a disruption did exist, the interval between its formation and the intrusion of the dykes may have been considerable, and it is not necessary to suppose that at the time of the intrusion any movement was in progress along the line.

In a few places the dykes have been folded after they were already in a foliated condition, an example of which occurs on the south-east side of Gorm Loch (three and a half miles east of Scourie).

In the north-east part of the middle belt, particularly near and in some broad yellow-weathering bands of crushed gneiss which run W.N.W. from Loch na Seilge to near Loch na Claise Fearna, the dykes are frequently crumpled, displaced, or represented by rows of lenticles. In some cases the constrictions between adjacent lenticles are probably due to thrust or crush-lines which have broken across an intrusion that was originally of regular dyke shape. In other cases the lenticles lie in lines parallel to the directions of the chief movements in the locality. A remarkable string of lenticles of this kind occurs two-thirds of a mile W.S.W. of Cnoc Bad na h-Achlaise and half a mile E.S.E. of the north-east end of Gorm Loch, the largest of which is about 100 yards long and 30 yards broad.

In many places, particularly in the middle belt, the foliation crosses the sides of dykes for great distances, and is parallel either to the early banding of the gneiss (in a modified form), or to a second foliation which crosses that banding in a direction parallel to the axial planes of fold. The later foliation in the gneiss corresponds to that in the dykes, and the schistosity common to both must have been produced at the same time. Where the foliation in the dyke agrees in direction with the early banding of the gneiss, then the latter is not in its original condition, but represents both the early banding and a second foliation which locally agrees in direction with the early banding, just as bedding and foliation often coincide in foliated sedimentary rocks.

The movements which were accompanied by the granulitisation of the gneiss and the foliation of the dykes were succeeded by others which mylonised the rocks, or which produced compact flinty material. The former condition chiefly presents itself in the granite-gneisses and pegmatites in the north-east belt, while the latter appears most commonly in the south-west district. A

Junction of basic dyke with banded pyroxenic or hornblendic Gneiss, $\frac{1}{4}$-mile south-west of Loch a Bhaid Daraich, Scourie, Sutherlandshire.

red granite-gneiss in the headland nearly a third of a mile north-west of Eilean Port a' Choit is mylonised in several bands, a few inches thick, nearly parallel to the old foliation planes. The matrix of the bands is extremely fine grained, but it encloses various small eyes of red felspar, and the movement planes display a faint sericitic lustre. Granite-gneiss bands in a partially mylonised condition occur also in the following places: three-quarters of a mile E.N.E. of Loch Stack Lodge, 300 yards south-east of Eilean Port a' Choit (at the head of Loch Laxford), a third of a mile and 350 yards S.S.W. of Badcall Quay, 300 yards and about 1000 yards slightly north of west of Laxford Bridge, and a third of a mile S.S.W. of the foot of Alltan Rabhail, a tributary of the River Laxford. In the first three of these localities, pegmatites have also been partly mylonised and converted into fissile schists with parallel red and white streaks. In the last two localities this type of deformation occurs in dykes foliated parallel to the side, and as the mylonised bands are likewise parallel to the margins of these intrusions, it is evident that the dykes formed lines of weakness along which movements were repeated. Throughout the north-east belt the effects of such movements are more conspicuous in the granite-gneisses and pegmatites than in the gneisses of the early complex.

Along the Ben Strome line of disruption flinty crush rocks are especially abundant in the part between a third of a mile E.N.E. of the top of Ben Strome and Allt na h-Airbh, whilst further east the materials in the thrust are finely foliated or granulitic, but show less cataclastic structure. It is possible that the granulitic and flinty crush rocks were being formed simultaneously in different parts of the same line of movement, but it is also possible that, as in other localities, the rocks were first granulitised or finely foliated, and then subsequently crushed, and that this later deformation has in certain places destroyed the evidences of the earlier stages of alteration.

In the middle belt various bands of yellow-weathering pyritous gneiss, often with small red garnets, are crossed by lines of fracture, most of which run nearly parallel with the strike of the

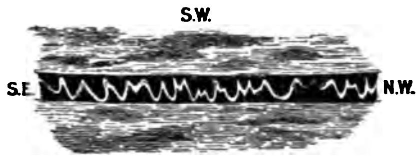


FIG. 6 ($\frac{1}{10}$).—Gneiss with a band that has been sharply contorted, probably in consequence of the rocks on one side having been moved past those on the other. Rather more than a third of a mile N.N.E. of the outlet of Gorm Loch.

early banding. These bands often give rise to little valleys or tracts which are smoother than the surrounding areas. One forms a flattish strip about half-way up the north-east side of

Ben Stack, and can be followed from Airdachuilinn past Loch na Seilge and the head of Loch an t-Seana Phuill to the coast near Tarbat (one mile south-west of Loch Laxford), the width, between the two lochs mentioned, varying from 100 to 200 yards. In some of these gneisses considerable movement has taken place along some of the foliation planes. Between two parallel straight bands of gneiss a narrow stripe may occasionally be noted, in which the laminæ are contorted along axial planes which strike at a considerable angle against the even gneiss on either side. An arrangement of this kind is well seen near the burn rather more than a third of a mile N.N.E. of the outlet of Gorm Loch, three and a half miles east of Scourie.

CHAPTER X.

KYLESKU TO LOCH BROOM.*

This district extends from Kylesku and Loch a' Chairn Bhain in the north to the Coigach mountains north of Loch Broom in the south. Bounded on the east and south by the great escarpment of Torridon Sandstone that stretches from the hills beyond Quinaig, south by Canisp and Cul Mor to Coigach, the total area occupied by the Lewisian gneiss, west of the post-Cambrian displacements, amounts to about 120 square miles. Though outlying masses of Torridon Sandstone appear to the west of the main escarpment, as for instance at Stoer and on Suilven, the Lewisian gneiss is continuous between Loch a' Chairn Bhain and Loch Enard, south of Loch Inver.

This tract is characterised by a succession of bare domes and ridges of rock, enclosing numerous lochs and tarns, being remarkably destitute of drift save in the area north-west of Quinaig. Though drained by the Inver and the Kirkaig and their small affluents, it does not possess a well-defined valley system. In the neighbourhood of Stoer and south of Loch Inver, the undulating rocky plateau rises to a height of 500 feet. Eastwards, however, as we approach the Torridon escarpment the elevation gradually increases till it reaches 1000 feet on Suilven, 1500 feet on Canisp, and about 2000 feet on Quinaig. In this district there are relics of the pre-Torridonian topography which are so conspicuously developed in the region north of Loch Maree. The best example occurs on the north-west slope of Quinaig, where a pre-Torridon hill, about 700 feet high, projects through the lower and is overlapped by the higher members of the red sandstone series.

One of the prominent characteristics of the topography of the area west of the great escarpment is the number of straight features, often traceable for long distances, largely determined by normal faults, lines of thrust and the trend of intrusive dykes.

Within the belt affected by the post-Cambrian movements, the Lewisian gneiss reappears above the Glen Coul and Ben More thrust-planes, forming detached masses, which together cover an area of about 15 square miles. Here the average elevation is higher than in the undisturbed area to the west, and in the wild corries round Ben More the gneisses with their intrusive dykes give rise to gigantic cliffs, ranging in height from 500 to 1500 feet.

* By B. N. Peach and J. Horne, with notes by L. W. Hinxman. The district described is comprised in Sheets 101, 102, 107, and 108 of the Geological Survey Map of Scotland on the scale of ($\frac{1}{63360}$) one inch to a mile.

GENERAL SKETCH OF THE LEWISIAN ROCKS.

In summarising the history of the Lewisian rocks in the district west of the escarpment of Torridon Sandstone, reference may be made, first, to the original members of the Fundamental Complex, second, to the sequence of dykes intrusive in that complex, and, third, to the series of pre-Torridonian movements which affected alike both dykes and gneiss.

Over a large part of the area between Loch a' Chairn Bhain and Enard Bay south of Loch Inver, the members of the Fundamental Complex still possess many of the characters of original igneous rocks, comprising ultra-basic, basic, and more acid types. Of these groups, the first, including pyroxenites and hornblendites, form here only an insignificant part of the series; the second, containing pyroxene granulites and garnet amphibolites, are much more largely represented; while the third, consisting of quartzose pyroxene gneisses, constitute the main portion of the unmodified gneiss of the region. Structurally they occur either as massive rudely-foliated igneous rocks, or as banded gneisses in which the constituents have a parallel or wavy arrangement. The ultra-basic rocks generally form lenticles traceable for no great distance, and the basic masses, though often in part free from banding, have frequently a rude foliation which usually coincides with that of the contiguous pyroxenic gneiss.

A noteworthy feature of the quartzose pyroxenic gneiss, conspicuously displayed on the south shore of Loch a' Chairn Bhain, on the sea-cliffs near Lochinver, and eastwards near Little Assynt, is the contortion and overfolding of the respective folia, which are truncated by planes oblique to the minute flexures. In 1888* these phenomena were ascribed to a gradual movement and piling up of the materials as the plutonic rocks underwent enormous pressure when in a solid form. But the researches of Sir A. Geikie† and Dr. Teall strongly support the conclusion that these structures must have been developed before the final consolidation of the rock masses.

Where not deformed by pre-Torridon movements the original gneisses of the complex are arranged in gentle anticlines and synclines, the axes of which usually run N.N.E. and S.S.W. or north-east and south-west, the outcrops of the successive bands forming parallel escarpments. After the development of the early foliation and the gentle folding, the original gneisses of this district were pierced by two sets of dyke intrusions. The earlier group, comprising rocks of basic and intermediate types, ranging from hyperite, gabbro, and diabase to biotite-diorite, is by far the most important and has the largest development. Crossing the plateau of Lewisian gneiss, generally in a W.N.W. direction, they clearly display their intrusive character in the

* "Report on the Recent Work of the Geological Survey in the North-West Highlands of Scotland," *Quart. Journ. Geol. Soc.*, vol. xliv., p. 389.

† "On the Banded Structure of some Tertiary Gabbros in the Isle of Skye." *Quart. Journ. Geol. Soc.*, vol. l., p. 645.

unmodified areas. Those of the later group, including ultra-basic rocks (picrites), cut the earlier, and their trend is more nearly east and west. This slight change in the direction of the picrite dykes implies a corresponding change in the trend of the earth stresses that gave rise to these fissure eruptions.

After the eruption of these igneous materials, the area was subjected to mechanical movements, whose effects are conspicuously developed in this region. The members of the Fundamental Complex were folded on vertical axes which trend in certain definite directions irrespective of the gentle anticlines and synclines that preceded these movements. The folding was accompanied by disruption lines or thrust-planes which deflected, attenuated, and deformed the dykes and developed new structures in the gneiss. Within the zone of folding the reconstruction of the gneiss may be partial and may be confined to a modification of the constituent bands along the old foliation planes. Sometimes an incipient newer foliation is developed at an oblique angle to the older one, that is rudely parallel to the axial planes of flexure or to adjacent lines of movement. Sometimes the reconstruction of the gneiss is so complete that new divisional planes have been set up and the lithological character of the rock has been changed. Hence we find, within these belts of later flexure and shear-zones, granulitic gneisses with hornblende and biotite, while beyond these limits the quartzose pyroxenic gneisses with their ultra-basic and early basic masses are characteristically developed.

Coincident with these modifications of the gneiss, structural changes appear in the dykes. All the various stages between the massive basic dyke and hornblende-schist, so well developed in the Scourie district, and between the unaltered picrite and talcose-schist are here admirably displayed.

Finally, there is conclusive evidence that the eruption of the basic and ultra-basic dykes and the widespread series of movements that affected both the gneiss and dykes were completed before the deposition of the basal breccias of the overlying Torridon Sandstone.

ULTRA-BASIC ROCKS.

In the present district these rocks have only a limited development, seeing that they are restricted to small lenticles, bosses, or knots in the quartzose pyroxenic gneiss in the unmodified areas. The largest mass occurs on the north shore of Loch Dhrombaig, six and a half miles north of Lochinver, where it forms the margin of that loch for one-third of a mile, and stretches north-west in irregular tongues for half a mile. Its lithological characters are variable: in some portions, pyroxenic minerals predominate with more or less olivine; in others, hornblende is the chief constituent. Garnets are abundant in places. Specimens taken from a quarter of a mile west of the village of Drumbag (Slides Nos. 3396, 3403, 3411, 3415) are referred by Dr. Teall to the olivine-hornblende-pyroxenite group (Group I. A).

Others taken from the western extension of the mass, at the sudden bend of the road, are described as garnet amphibolite (III. A.) and hornblendite with pale-green hornblende (I. B.). In this mass, which is more or less distinctly foliated, the direction of the foliation runs parallel to that of the surrounding gneiss. The irregular outlines of the mass suggest the folding of the gneisses at an early stage of the original complex.

Rocks allied to the banded pyroxenites occur at intervals over the rocky plateau between Quinaig and Stoer, as, for instance, on the north arm of Gorm Loch Mor, on the west side of the northern arm of Loch Poll, and again between Loch Poll and Clashnessie Bay. In most of these examples they appear as thin foliated lenticles, banded with the grey pyroxenic gneiss. One instance on the north margin of Loch na Bruthaich (one mile north-east of Clashnessie) is a hornblendite with pale-coloured hornblende in aggregates. (I. B., No. 3402.)

An important mass of hornblendite, about a quarter of a mile long, occurs on Fairait Mhor, two and a half miles W.N.W. of Lochinver, where it has been quarried for millstones. The rock is almost flat and intercalated in and folded with the pyroxenic gneiss. Like other lenticles of the same material, this mass is cut by one of the north-west basic dykes and traversed by shear-zones. Again, one mile south of Lochinver and a quarter of a mile south of Loch na Doire Daraich, a sheet of ultra-basic rock, about 50 feet thick, forms a crag near the hill-top. It belongs to the pyroxenite group, and is there interbanded with the grey pyroxenic and hornblendic gneisses, both rocks having a common dip. At the extreme north-west end of Suilven a band of soft ultra-basic rock, in which lies a chain of lochans, is traceable, and again at the southern limit of this district, at the eastern end of Loch an Gainmheach, south-west of Cul Mor, two irregularly-shaped masses of ultra-basic rock show more or less alteration into serpentine. On the islands half-way down Loch Assynt and at Kylesku Ferry, lenticles of ultra-basic rock appear; in the latter case they have been referred to olivine-hornblende pyroxenites and hornblende pyroxenites (Group I. A.). Other examples might be quoted which have been recorded on the six-inch maps, but these are sufficient to show that, while these rocks form an insignificant part of the complex, they occur at intervals throughout this district.

In addition to these larger bands and lenticles, innumerable lumps and knots occur in the grey gneiss, from a few feet to a few inches in diameter, consisting mainly of hornblendite, which are analogous to the basic knots in the granite of Criffel, in Galloway, and may probably have had a similar origin.

EARLY BASIC ROCKS.

The members of this group have a much larger development, and are represented by hypersthene-augite plagioclase rocks (II. A1), by augite-plagioclase rocks (II. A2), by garnet amphibolite (III. A1c), and pyroxene granulite. The distribution and relations of some of the more prominent masses may here be indicated.

About two miles south-west of the village of Lochinver, on the promontory of Baddinaban, a grey basic mass may be seen, having an even texture with dark streaks full of small garnets, which are sometimes crowded together. It is well exposed on the cliffs on the south side of Strathan Bay and at the little boat harbour at Baddinaban, where it is rudely banded and in general appearance resembles a massive igneous rock. It is traversed by several of the north-west basic dykes, the latter having chilled margins along their course. In this eruptive mass Dr Teall has identified two types of rocks, (1) dark medium-grained, containing hypersthene, augite, and plagioclase, with and without garnets, the variety without garnet being a typical example of the Baltimore gabbros; and (2) augite-plagioclase rocks without hypersthene. It is noteworthy that the grey acid pyroxenic gneiss traverses this basic rock in anastomosing veins, without chilled margins, which become banded and interlaced with the basic material.

About four miles north-west of Lochinver and one-third of a mile south of Loch a' Ghleannan Shalaich, another prominent area of early basic material appears, embracing different types of rock. Its long axis, measuring about half a mile in length, runs north-east and south-west, and varies in breadth from 100 to 400 yards. At the south-east end it is rudely foliated, the strike of the foliation being north-east and south-west in common with that of the surrounding pyroxenic gneiss. Specimens taken from this mass are referred to two groups—garnet-amphibolite (III. A1c), and hornblendite (I. B2). On its north-west and south-east sides, it is truncated by the north-west basic dykes, the boundaries between the two being clearly defined. About one-third of a mile south-west of this place and to the north of Loch Beannach, several masses of garnet-amphibolite are banded with the grey pyroxenic gneiss and share in its folds. They are rudely foliated, the strike being north-west and south-east. Again, about five miles N.N.W. of Lochinver and one mile south of Clashnessie, between Loch nan Lub and Loch-na-h-Uidhe-Doimhne, an area of early basic material extends for half a mile and forms several rocky hills. Some parts of it are devoid of foliation, others show a rude banding. It is an epidote amphibolite (III. A1a). An interesting feature here is the plexus of acid veins, composed of granulitised andesine felspar, that traverse the basic rock. As the mass lies between two prominent shear-zones and is itself traversed by lines of movement, the granulitisation of the andesine and the saussuritic aggregates referred to by Dr. Teall may with much probability be regarded as of secondary origin.

The remaining area of rocks of this group lies about five miles south of Lochinver, between Loch Skinaskink and the western sea-board. Here a large crude mass showing little foliation is in the main a hornblende-plagioclase-rock, occasionally garnetiferous. It is traversed by numerous veins of quartzose pyroxene-gneiss, which near the margin of the basic rock become so abundant that both merge into the surrounding gneiss complex. From the evidence here adduced it is apparent that, like the smaller lenticles of ultra-basic material, these early basic masses are older than the quartzose pyroxenic gneiss, and that both rocks share in the rude foliation which preceded the eruption of the basic dykes.

PYROXENE-GNEISS.

In this district, as elsewhere, the dominant member of the Fundamental Complex in the unmodified areas is the pyroxene-gneiss of Dr. Teall's classification (II. B). In addition to the pyroxene, this type contains hornblende and biotite as original constituents. The characteristic features of the group are the abundance of blue or semi-opalescent quartz (see Chap. IV. for explanation of this tint) and the carious weathering of the surface due to the decomposition of the felspar and ferro-magnesian constituents and the projecting network of quartz. A gradation can frequently be traced from a type rich in ferro-magnesian minerals to a variety composed mainly of quartzo-felspathic material. Throughout the district, the pyroxene-gneiss with hornblende and biotite passes imperceptibly into grey hornblende gneiss with biotite, in which both the hornblende and biotite occur as aggregates. The quartz of this hornblende gneiss contains the same hair-like inclusions (Chap. IV.), and the felspar is likewise identical. The secondary hornblende replaces the augite in such an irregular manner that the rock may pass, in a short distance, from a pyroxenic to a hornblendic gneiss.

The pyroxene-gneiss may be examined in the shore sections east and west of Kylesku, on the south side of Loch Glencoul and Loch a' Chairn Bhain, and on the coast north and south of Lochinver. Inland it spreads over wide tracts from Drumbag south by Little Assynt and the Kirkaig river to Loch Skinaskink, presenting throughout in the unmodified areas the same general characters. In places, as, for instance, near Little Assynt and along the south shore of the upper part of Loch Assynt, the rocks are so massive as to present only a slight parallel arrangement of the constituents. At the latter locality they have locally undergone alteration due to decomposition, and have a waxy appearance owing to the development of secondary epidote. In other areas, the banding is more or less marked, and the outcrops of the successive bands make characteristic features on the hill slopes, as on the rocky platform west of the Torridon escarpment of Quinaig and on the plateau near Suilven. The maps (107 and 101) show the disposition of the flexures of these original gneisses and the considerable variation of the strike owing to undulation. Yet the long axes of the folds frequently run in a N.N.E. or north-east direction. The subsequent modifications

Junction of Gneiss and dyke ; dyke on the right, Gneiss on the left. Secondary movement has taken place along the nearly vertical junction plane. Creag a' Mhail, north side of Scourie Bay, Sutherlandshire.

of the members of the Fundamental Complex in strike, dip, and petrographical characters as displayed in this district will be described in connection with the pre-Torridonian movements.

PRE-TORRIDONIAN DYKES INTRUSIVE IN THE FUNDAMENTAL COMPLEX.

In no portion of the whole region of North-West Scotland are these dykes more conspicuously developed than in the district now under description. Their abundance and general distribution are well illustrated on the one-inch maps (Sheets 101, 107). They present here the usual petrographical types, which may be classified as (1) an ultra-basic group, comprising picrites; (2) a basic group, which is the most abundant, and includes olivine-norite, hyperite, gabbro, diabase, enstatite-diabase, and hornblende-enstatite-diabase; (3) intermediate rocks comprising biotite-diorites. The trend of the basic series is generally W.N.W., that of the ultra-basic more nearly east and west, and that of the intermediate north-east, and in one instance W.N.W.

The descriptions already given of the general features of the basic dykes between Scourie and Kylesku are applicable to this district. The uprising of the igneous materials along vertical or highly-inclined fissures transverse to the early foliation of the gneiss, the frequent brecciation of the walls of the fissures, the branching and reuniting along their course, the intersection of one dyke by another of much the same mineral composition, the presence of close-grained or "chilled" margins, the contrast in texture between the interior and sides of the larger intrusions, and in some instances the mineral banding due to original segregation—all these features are displayed in the district between Kylesku and the Coigach mountains.

The dykes vary much in breadth and visible length. The broadest example appears south of the Kirkaig, and at certain points in its course is 200 yards wide. Others vary from 20 to 50 yards in breadth. The remarkable persistence of these dykes is a striking feature in this district. The larger examples have been traced for twelve miles across the plateau of Lewisian Gneiss from the base of the Torridon escarpment to the western seaboard.

Certain typical examples of the various groups may now be indicated. A dyke of special interest may first be noticed, as it furnishes a link between the basic and ultra-basic types. It occurs on the north shore of Loch Assynt, at Rudha na Doire Cuilinn, four miles W.N.W. of Inchnadamff, and is described by Dr. Teall as an olivine norite (2319). The relations of this dyke to the normal types of the basic intrusions is not there apparent—a point of some interest, in view of the fact that the latter are cut by the ultra-basic group. About two miles west of Tomore Lodge, Loch Assynt, on the west side of Loch an Ruighean, an allied type is represented in a dyke of hyperite.

An interesting feature of the basic group in the Assynt region is the occurrence of varietal types in the same intrusion. For example, the dyke that runs by the side of the road north of

Loch Assynt, in the direction of Tomore Lodge, and crosses the small promontories north-west of Ruadha an Doire Cuilinn, shows marked variation. A series of specimens (3040-3045) indicate that it ranges from a hyperite and enstatite-diabase in the centre to an epidiorite or epidote-amphibolite at the margin where there are signs of deformation. Another example of rapid variation is furnished by the conspicuous dyke, 50-70 yards in breadth, that follows the southern shore of Loch Glencoul for three-quarters of a mile east of the mouth of the Unapool Burn. A series of specimens (8600-8605) from Cona Craig, a hillock formed by the intrusion near its eastern end, and taken at various distances from its edges, include rocks described as diabase, gabbro, and epidote-amphibolite.

The dykes of epidiorite or hornblende-plagioclase-rocks are separable into two groups, according to the presence or absence of igneous structure. An example of the igneous structure, with lath-shaped interstitial felspars, occurs in the dyke that runs immediately below the road and close to the shore of Loch Assynt, about four miles west of Inchnadamff. The typical rocks of the group in which igneous structure is not apparent are essentially composed of plagioclase and hornblende, with some quartz. These include a large number of the dykes in this region.

A typical instance of segregation before the solidification of these basic intrusions is afforded by the massive dyke, to which reference has already been made, near the river Kirkaig. Emerging from beneath the Torridon Sandstone at the base of the north slope of Cul Mor, it has been traced along the south side of Loch Veyatie, by the south of the Fionn Loch, thence across the Kirkaig a little above the waterfalls, till it passes out to sea at Kirkaig Point. The rock is an enstatite-diabase, merging, in places, into an epidiorite at the edge. The centre of the dyke shows knots and strings of acid material, which, under the microscope (3905-3908), are found to be composed of alkali-felspar, plagioclase, quartz, biotite, hornblende, and epidote, forming a hornblende-granite. Here there is a repetition of the phenomenon which is such an invariable feature of the Fundamental Complex traversed by this dyke. Another example of differentiation with rude mineral banding is found in the dyke between Canisp and Cama Loch, a quarter of a mile north-west of Loch a' Chroisg, which is a hornblende-diabase, passing into epidote-amphibolite. The rude banding is due to the parallel arrangement of the felspathic and ferro-magnesian constituents, similar to that in the pyroxene-hornblende-gneiss of the older complex. The central portion is more acid than the outer parts. In places the rock is sheared and becomes a schistose epidiorite. The thin basic dykes which abound in the region do not show the variation in character here referred to. For the most part they consist of fine-grained epidiorite.

Only three examples of the intermediate group of intrusions, consisting of biotite-diorite, have been mapped in this district. One, which varies from 33 to 70 yards in width, occurs at Allt a'

Mhuillin, close to the road, about two miles south-west of Loch Inver, and stretches from Loch Bad na Muirichinn to the sea at Baddinaban. Its course is about north-west and south-east, it intersects one of the normal basic dykes, and displays lustre-mottling as a conspicuous feature in the field. The two other dykes, only a few feet in breadth, have been met with north of Little Assynt, one east of Loch Beannach, the other east of Loch an Ruighean. Their direction—north-east and south-west—is exceptional, and they are traceable only for short distances. They are characterised by large felspars—oligoclase-andesine—set in a compact dark matrix.

The ultra-basic dykes, composed of olivine and augite with some reddish-brown biotite, are of special interest. Like the members of the basic group, they rise along well-defined fissures with more or less vertical walls, which are slightly oblique to the trend of the older lines of eruption, as their course is more nearly east and west. Owing to their ultra-basic character they frequently decompose and give rise to long narrow slacks or clefts forming marked features in the landscape. In some rare cases they reach as much as 100 yards in breadth.

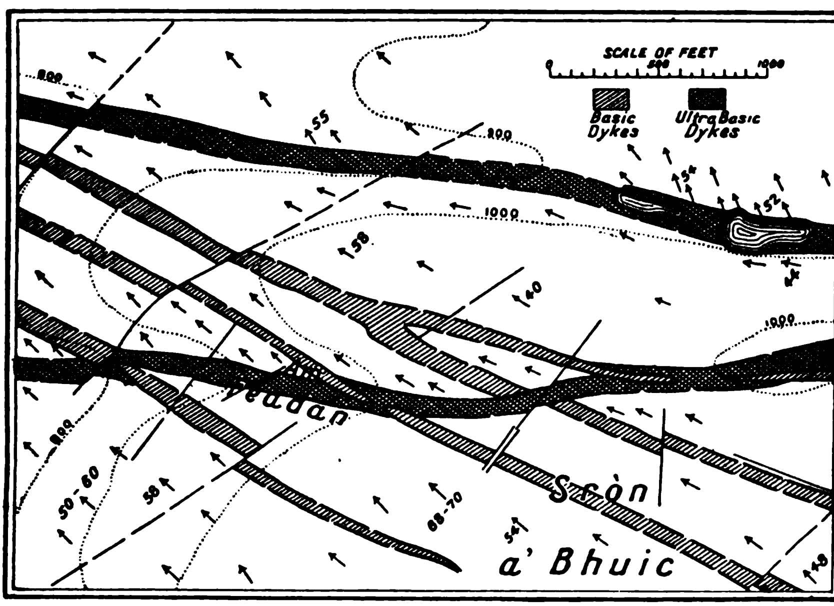


FIG. 7.—Intersection of the older epidiorite dykes by the later picrite intrusions on Sron a Bhuic, two miles south of the foot of Loch Assynt.

There is ample evidence that the picrite dykes are later than the basic series, for in many places the intersections are exposed. The relations between the two, however, are somewhat peculiar. In the accompanying Figure 7, which is a transcript of part of the six-inch map of an area near Sron a' Bhuic on the plateau midway between the foot of Loch Assynt and the west end of

Suilven, the intersections are well displayed. It will be seen that, in the case of the more southerly of the two ultra-basic dykes in this diagram, tongues of picrite run along the outer margins of the older epidiorite intrusion and then die out. At the point of crossing the width of picrite is sometimes narrower than the normal breadth of that intrusion on either side of the epidiorite. In other cases both the gneiss and the basic dykes have more or less vertical walls, up which the ultra-basic material has arisen.

Regarding the distribution of these picrite dykes, a glance at Sheets 101 and 107 will show that they are mainly restricted to a belt of ground, about three miles broad between Loch Inver on the west and the lower end of Loch Assynt on the east. Outside these limits they are of rare occurrence.

The dyke which has been taken as the typical example of the group occurs one mile north-east of Little Assynt on the west shore of Loch Assynt, and about half a mile above the foot of that loch. It is there 15 yards broad. Westwards across the plateau of pyroxene-gneiss it can be traced at intervals to Loch Beannach, near which it bifurcates and is truncated by a N.N.E. fault. In the field its conspicuous feature is the occurrence of large individuals of a green pyroxene in a dark fine-grained matrix. (See Chap. VII.)

A similar dyke crosses the promontory on the south side of Loch Assynt, and can be traced east to Easter Tobeg. It reappears on the promontory of Torr an Eilein, where lustre mottling is very apparent. Like the type just described, this intrusion contains large green pyroxenes and the chief constituents are alike, but Dr. Teall regards it as occupying a position intermediate between peridotite and olivine-gabbro (3307, 8123).

Two parallel ultra-basic intrusions, one of which may be a continuation of the Torr an Eilein dyke, can be traced for two miles across the strip of gneiss that lies between Beinn Garbh and the upper part of Loch Assynt. These dykes are composed of a hard greenish-black rock belonging to the picrite group, with no recognisable felspar, but showing conspicuous lustre-mottling. Both exhibit the more common type of alteration into serpentine.

South of these examples a remarkable group of dykes can be traced from the Torridon Sandstone escarpment between Canisp and Beinn Gharbh, across the Lewisian gneiss, to the coast at Achmelvich Bay north of Loch Inver, and to Clachtoll, near Stoer. Two members of this group have been specially studied on account of modifications developed by pre-Torridonian movements, to which reference will be made in the sequel (p. 170). The more northerly crosses the river Inver at Inveruplan, and forms the hollow along which the road runs at Brackloch. The southern one traverses the Inver a quarter of a mile further south and appears at the roadside at Loch an Eun, about one mile north-east of Lochinver. Westwards these two dykes unite near Riecairn, a mile and a half N.N.W. of Lochinver, and the western prolongation is visible in many places at the roadside between Riecairn and Clachtoll.

Near the southern limit of the district an ultra-basic dyke forms a well-marked cleft in Allt Gleannan t-Srathain, north-west of Loch Skinaskink. In the northern part only a single example has been found. It runs along the course of the stream that flows W.N.W. through Gleann Ardbhair (about one mile south-west of Loch a' Chairn Bhain) into Loch Ardbhair. Here also, owing to the softer character of the rock, the dyke has given rise to a long deep hollow.

PRE-TORRIDONIAN MOVEMENTS.

Throughout the district now under description abundant evidence has been obtained of the earth-stresses to which the Lewisian rocks were subjected, and which resulted in the violent folding of the members of the Fundamental Complex in definite lines of disruption or thrust-planes and in well-marked zones or belts of secondary foliation, whereby considerable changes in petrographical character were superinduced upon the gneiss and its dykes. Inasmuch as many of the phenomena characteristic of these pre-Torridonian movements, which have been described in detail in the section relating to the district between Laxford and Kylesku, are repeated in the ground to the south, it will be sufficient to give here merely an outline of the direction and character of these movements and the modifications of the rock-types resulting from their operation.

Three distinct lines can be followed along which the movements have taken place—(1) W.N.W. and E.S.E., that is more or less parallel with the basic dykes; (2) nearly east and west; and (3) in certain exceptional cases north-east and south-west. The distribution of these shear zones may be readily grasped by referring to Sheets 107 and 101, from which it will be seen that they are specially numerous in certain areas.

Examples of the first system—those that more or less coincide with the trend of the dykes—are well developed along a belt that stretches from the valley between Canisp and Suilven, W.N.W. by Druim Suardalain, and the river Inver, between Brackloch and Loch Inver, thence to Achmelvich Bay south of Clachtoll. They likewise traverse the plateau along the valley of the Kirkaig, W.N.W. by the Fionn Loch to the coast at Strathan south-west of Loch Inver. Some with a similar trend have been mapped south of Allt Gleannan t-Srathain, north-east of Loch Skinaskink. Those which run nearly east and west are numerous along the western part of the plateau between Achmelvich Bay, north-west of Loch Inver, and Clashnessie Bay, N.N.E. of Stoer. Eastwards many of them seem to die out or disappear, while others coalesce and are traceable for miles. Perhaps the best examples of this system form the group that extends from Clachtoll east by Loch Crocach, thence by the north slopes of Cnoc an Dubharlainn to Loch a' Ghleannain Shalaich and onwards in the direction of Tomore Lodge by Loch Assynt. The lines of movement trending north-east and south-west are rare, but some examples occur to the south-east of Loch Crocach, near Loch Skinaskink, and at other localities. The planes of disruption are generally more or less vertical, but in exceptional instances are nearly horizontal.

In this district the effects of these movements upon the rocks have been similar to those above described from the Laxford and Kylesku ground. It will not, therefore, be necessary to repeat details already given. It may suffice to select a few typical examples of the modifications, which are here displayed. We may consider first the modifications superinduced upon the gneiss, and secondly those exhibited by the dykes.

(1) Modifications of the Gneiss.—The system of east and west lines of displacement has here, as elsewhere, given rise to narrow and well-defined shear-zones. A typical illustration of this modification may be seen west of Loch a' Ghleannan Shalaich, two miles W.N.W. of Tomore Lodge, Loch Assynt, where several parallel lines of disruption may be traced, showing newer foliation. One of these varies from 50 to 70 yards in breadth. The strike of the foliation of the pyroxenic-gneiss is north-east and south-west or north-west and south-east, but on approaching this thrust-plane the gneiss is folded and dragged into parallelism with the line of movement—that is, nearly east and west. Coincident with this folding and deflection of the original gneiss, important modifications have been effected in its constituent minerals along the old foliation-planes. The opalescence of the quartz has disappeared, biotite has been developed, and the felspars have been granulitised. Within the narrow shear-zone the reconstruction of the rock is complete, and it appears as a fine granulitic micaceous gneiss whose foliation planes dip at high angles towards the south. Occasionally a lenticle or phacoid of the modified pyroxene hornblende gneiss appears within the narrow belt of reconstructed gneiss showing the intermediate stage of change. Other similar instances of metamorphism might be quoted from this district along the east and west lines of displacement.

The most prominent belt of modified and reconstructed gneiss connected with the W.N.W. lines extends from the south slope of Canisp, through the Canisp deer forest, and across the Inver above Loch Inver Bridge to Achmelvich Bay. At certain places, as above Loch Inver Bridge, the boundary line is well defined between the adjacent pyroxene-hornblende-gneiss and the flaggy hornblende-biotite-gneiss. Along this line the flaggy gneisses have been folded on vertical axes, the planes of foliation being nearly vertical. A rude anticlinal arrangement is occasionally observable beyond Loch Inver Bridge, the planes being vertical in the centre and dipping away on either side. On the line of this belt of secondary foliation at the shore beyond Achmelvich Bay a fine section is exposed on the seacliff within a space of 50 yards, showing the relation of these shear-planes to the pyroxene-hornblende-gneiss, as represented in the accompanying figure. It will be seen that, between the lines of

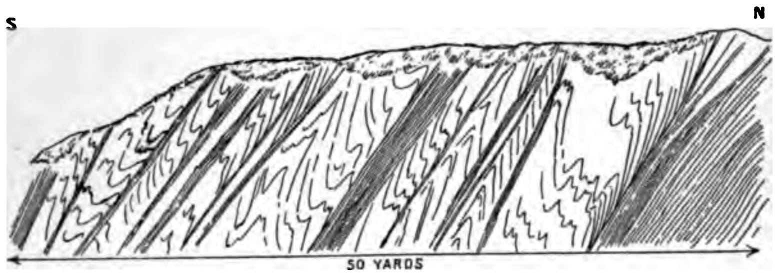


FIG. 8.—Relation of newer to older planes of foliation in pyroxenic and hornblendic gneiss. Rudha Leumair, 3¾ miles north-west of Lochinver.

disruption, the folia of the older gneiss are sharply contorted and dragged into parallelism with the disruption planes. In these intervening bands a partial modification of the constituents has taken place, but within the shear-zones the reconstruction is complete. Here the same phenomena are observable as those already described; the granules of quartz loose their opalescence, are elongated and become granulitic, biotite is developed from the hornblende, and the felspars are granulitised. The rock becomes a granulitic gneiss, wherein the foliation planes dip at high angles to the S.S.W.

On the promontory east of Camas nan Bad (two miles north-east of Drumbag) two narrow shear-zones run north-west and south-east through a mass of pyroxene-gneiss, the strike of the old foliation planes being oblique to the lines of shear and the dip being at low angles. Under the microscope, a specimen (3401) shows that the reconstructed rock is a biotite-gneiss, in which the biotite occurs in aggregates (IV., 2).

In some localities, as between Stoer and Clashnessie Bay, the reconstruction of the gneiss has taken place along nearly horizontal planes and without any apparent deflection of the associated dykes. In such cases there may have been interstitial movement of the constituents and recrystallisation under compression.

In the north-western part of the district between Drumbag, Gleannan Salach, and Loch Poll, the prevailing type of rock is a flaggy well-banded hornblende-gneiss, which seems to have undergone a certain amount of reconstruction. Though there are many local flexures, the general strike is approximately north-west. These flaggy gneisses are particularly well developed in Oldany Island, where excellent sections are exposed on the coast. Along the west side they have a fairly uniform strike, and for a distance of nearly a mile are vertical or nearly so. They often contain biotite in addition to the hornblende, and at several places thin intercalations appear in whch that mineral is the chief ferromagnesian constituent. On the west side of the inlet of Baile na Cille, the rocks include a large proportion of felspar, and are sometimes epidotic, with abundant semi-opalescent quartz. The strike of the gneiss on the north and east sides of the island is more irregular, and the rocks are often folded and crumpled. The contortion of these banded gneisses is most intense on the promontory of Cnoc a' Mhoil Bhain and the islands that surround it, and also on the cliff face along the west side of Eilean nan Gobhar, which lies to the S.S.W. of Eilean nan Uan. In this section the folds of the banded gneiss and basic rock are distinctly cut off by a set of planes that cross the cliff face at various angles and have all the appearance of thrust-planes.

Apart from the bands of wholly reconstructed micaceous gneiss developed along the lines of pre-Torridonian movement, there are, in several parts of the district, belts of flaggy granulitic gneiss, which owe their present structures to a certain amount of modification of the rocks of the early complex. Rocks of this type are developed along the shores of the upper part of the hamlet of Nedd (one mile E.S.E. of Drumbag), where the flaggy well-foliated gneisses dip W.N.W. at 15°-25°. The mica is orientated along the divisional planes, while occasional lines of striping can be observed. A belt of similar rocks extends E.N.E. from Glenleraig and past Loch nan Claidhmhnean (two and a half miles east of Drumbag), biotite being abundant in the gneiss to the east of that loch. Again, at the village of the Stoer, on the cliff east of the Torridon Sandstone strata, a belt of similar flaggy gneisses with biotite on the divisional planes, strikes nearly east and west in accordance with the direction of the shear-zones in that area. Their general inclination is south at angles from 50°-60°. On either side of this belt the hornblende-gneiss appears in a partly modified form, but still shows the original foliation-planes.

South of Clachtoll, in the direction of Riecairn, excellent examples may be noticed of the development of incipient newer foliation at an oblique angle to the older one. This change is best seen where the original banding is well defined and where the folia have undergone rapid crumpling and contortion. In such cases, the biotite-flakes are arranged in lines parallel to the axial planes of folding, and where the puckering is fan-shaped there is a corresponding disposition of the biotite. This double foliation is well displayed on some of the cliff-faces by the roadside north of Riecairn, where the gneiss is contorted close to disruption lines.

(2) Modifications of the Dykes.—The alteration of the dykes in the present district so closely resembles the changes already noticed in Chapter IX. that it will suffice to select a few typical examples characteristic of the whole series.

The promontory, Rudha nam Fias, at the mouth of Loch Chairn Bhain, is traversed by three lines of shear, which appear to be branches of the disruption line that passes eastwards beyond that sea loch and Loch Glendhu. They are marked by the usual narrow bands of sheared gneiss, in which the foliation is parallel

Portion of the dyke shown in Plate XXI. where it is crossed by a zone of disturbance. The lower part is composed of massive Epidiorite; the upper part of Hornblende-schist. Creag a' Mhail, north side of Scourie Bay, Sutherlandshire.

to the line of movement, with a southerly dip at high angles, in contrast to the gneiss on either side. The epidiorite dyke that appears on the shore three-quarters of a mile north of Kerracher Bay, as it approaches the crush-line, rapidly diminishes in breadth, and is deflected towards that line. This attenuation is accompanied by the usual crushing, shearing, and conversion of the rock into hornblende-schist, the foliation being more or less parallel to the plane of thrust. A short distance further west, the line of movement deflects another thinner dyke, and at this point both intrusions appear to be disrupted and displaced for a distance of several hundred yards. Crushed dyke-material is seen again on the further side of a normal fault that shifts the shear-line a few yards to the north, and the dyke finally resumes its normal course as it passes into the sea on the west side of the promontory.

This example clearly illustrates the deflection, thinning, and conversion of the epidiorite into hornblende-schist, and further, the westerly movement of all the materials on the north side of the disruption line. Many similar instances might be adduced in connection with the numerous shear-lines on the plateau between Drumbag and Little Assynt.

In addition to these modifications of the basic intrusions, it may frequently be observed, within these east and west shear-lines, that the dyke is wrenched into a series of isolated lenticles or "phacoidal" masses imbedded in a zone of reconstructed granulitic gneiss. Perhaps the best illustration of this phenomenon in the present district is to be found along the prominent line of disruption west of Loch a' Ghleannain Shalaich, two miles W.N.W. of Tomore Lodge, Loch Assynt, already referred to. Following this shear-zone westwards for about three-quarters of a mile from the south-east branch of that loch, the observer may note that a thin basic dyke, which enters that zone from the north, is disrupted and severed into seven detached lenticles of hornblende-schist, from 30 to 130 yards in length, all arranged parallel to the line of the thrust and to the foliation planes of the reconstructed micaceous gneiss by which they are surrounded.

The W.N.W. movements frequently only partially affect the dykes that run in the same direction. The margins of the intrusions have been rendered schistose while their central parts and the adjacent gneiss remain comparatively unaffected. Such marginal strips of schist are a common feature among the basic dykes. Between this stage and the conversion of the whole dyke into hornblende-schist a lenticular or phacoidal structure is sometimes met with, when isolated portions of crushed basic rock are surrounded by wisps and bands of hornblende-schist. This feature is exhibited in the dykes in Canisp forest, about 2½ miles south of Little Assynt. Again, when the lines of shear in this direction coalesce, then the basic dykes are entirely converted into hornblende-schist, sometimes with a platy parallel foliation and abundant biotite on the divisional planes. These phenomena are admirably displayed along the belt extending from Canisp by Lochinver Bridge to Achmelvich Bay.

The evidence of the conversion of parts of the ultra-basic dykes into schists by the W.N.W. movements is no less clear. In the case of the picrite dyke that crosses the Inver at Brackloch and Inveruplan, the rock at the former locality is only slightly more altered than the typical example near Little Assynt, being still massive and containing olivine, hornblende, chlorite, and carbonates. At Loch nan Eun (a mile west of Brackloch), where the west branch of this dyke is affected by a shear-line, only a few grains of olivine are left, while the amount of chlorite and hornblende is increased. Further west, at a point 2¼ miles north-west of Loch Inver and 4½ miles by road, the prolongation of the Brackloch dyke, is converted into a schist with chlorite, hornblende, and knots of siderite. Still westwards, on the sea-coast, 3½ miles north-west of Loch Inver, and 300 yards south of the road to Stoer, a picrite dyke is found which appears to be a branch of the Brackloch intrusion. At its northern edge it is massive, but part of it is affected by shearing. A series of specimens (2938-2843), when examined under the microscope, show progressive alteration into a perfect schist composed of chlorite, pale hornblende, and talc.

Apart from these main directions of movement, there is still another group trending north-east and south-west which has led to the reconstruction of both the basic dykes and gneiss. In the neighbourhood of Clashnessie Bay north of Stoer, a belt has been observed where the strike of the newer foliation is north-east and south-west, and where the interstitial movement of the constituents has been along nearly horizontal planes, without much, if any, disruption of the dykes. These phenomena are well seen about a third of a mile south-west from the bridge across Clashnessie Burn, where the foliation of the hornblende-schist dips gently south-east—that is nearly at right angles to the course of the dyke. In connection with the deformation of the dykes, it may be mentioned that quartz-veins frequently appear in the bands of hornblende-schist.

This district furnishes abundant evidence that the pre-Torridonian movements which led to the reconstruction of the gneiss and dykes were completed before the deposition of the Torridon Sandstone. For example, at Stoer, where there is an important outlier of that formation, the numerous shear-zones can be traced up to its margin, while pebbles of the deformed gneiss and of hornblende-schist occur in the bands of conglomerate which there appear. In like manner the lines of disruption can be followed up to the base of the Torridon Sandstone on Canisp, but they do not enter the sandstone. They likewise pass under the escarpment of Cambrian quartzite between Canisp and Suilven. Pebbles of the reconstructed granulitic gneiss and of hornblende-schist are found in the basal Torridon breccias in Canisp and at the east end of the Suilven outlier.

INLIERS OF LEWISIAN GNEISS ABOVE THE GLENCOUL AND BEN MORE THRUST-PLANES.

Detached masses of Lewisian Gneiss appear in the areas affected by the post-Cambrian movements. Of these masses, the largest occur on Ben More, Assynt, and Sgonnan Mor, S.S.E. of Braebag, above the Ben More thrust-planes. Smaller areas are found in Glas Bheinn and Beinn an Fhurain, north and east of Inchnadamff, on the hill between Ledbeg and Cama Loch, and at other places.

All these various masses include certain well-marked types, which are characteristic of the Fundamental Complex, between Scourie and Kylesku and in the Loch Inver region. These comprise ultra-basic rocks (pyroxenites and hornblendites), grey pyroxene-gneiss, and hornblende-gneiss with blue quartz. The general strike of the Lewisian gneisses in the Ben More inliers is N.N.W. and S.S.E., and the early foliation is quite apparent; indeed, the old structures of the early basic masses can be readily recognised in all the corries on the north-east face of Ben More, in Corrie Mhadaidh, north-west of Ben More, and on Sgonnan Mor.

A remarkable feature is the abundance of basic dykes that traverse the gneiss and still preserve their north-west trend, though the detached and moved masses in which they occur overlie the Glencoul and Ben More thrust-planes. These dykes are well exposed on the gigantic cliffs and on the rocky floors of the great corries of Ben More. Most of the dykes consist of massive epidiorite, in some cases reaching 100 yards in breadth, and usually showing strips of hornblende-schist along their margins. Dykes of picrite also occur, as, for instance, on the plateau west of Dhu Loch Beag, about three miles up the Oykel valley from Kinlochailsh, and again on the south-west face of Sgonnan Mor, close by the unconformable base line of the Torridon Sandstone.

Along its line of junction with the Torridon and Cambrian strata, the Lewisian gneiss has been sheared, rendered schistose and reconstructed, the planes of schistosity being parallel with the post-Cambrian thrust-planes.

Brief reference may be made to the normal faults that traverse the Lewisian gneiss west of the post-Cambrian displacements which give rise to many of the linear features in that plateau. On referring to Sheets 107 and 101, it will be seen that they belong mainly to one system, trending in a north-east and south-west direction. The existence of these faults has been proved in many cases by the slight change in the outcrops of the dykes and sometimes by the brecciation and discolouration of the gneiss. Other lines of displacement run in a W.N.W. and north-west direction. The chain of lochs and hollows that extends from Loch Assynt by Gleannan Salach to Loch Poll affords an excellent example of the influence of the W.N.W. dislocations upon the topographical features of the country.

CHAPTER XI.

GRUINARD DISTRICT.*

The district of Lewisian gneiss now to be described stretches from Enard Bay across the Coigach Hills and the mouths of Loch Broom and Little Loch Broom to Gruinard Bay, and thence inland southwards to a line drawn through Loch an Eilein, Loch na Moine Buige (the north-western branch of the Fionn Loch), Feachaisgean on the east side of Fionn Loch, the northern slopes of Beinn a Chàisgein Mòr, Lochan Feith, and a little south of Lochan a Bhràghad, to the head of Gleann na Muice. Several patches of thrust Lewisian gneiss, in the neighbourhood of Ullapool and in Strath Kanaird, which lie far to the east, will also be included in this chapter.

The patches of moved gneiss near Ullapool and in Strath Kanaird, as well as those unmoved inliers in Coigach, in the islands in Loch Broom, and near the entrance of Little Loch Broom, form comparatively low ground, though one of the masses south of Ullapool rises to about 1250 feet above sea-level. South of Gruinard Bay the undulating craggy ground east of the Gruinard River rises to 985 feet above the sea in Carn na Beiste, and to 1283 in Carn nam Buailtean. West of this river is Creag-Mheall Beag (1139), whence the ground mounts up rapidly to the southward, until in some places near Loch Toll a' Mhadaidh it reaches above the 2250 feet contour-line. Beinn a' Chaisgein Beag, the most conspicuous isolated hill in the district, is 2234 feet. Nearly all the ground west of the Little Gruinard River is below 700 feet. The only important streams are the Gruinard River which runs through Loch na Sheallag, the Little Gruinard River draining the Fionn Loch, and the Inveriavanie River which comes from Loch Toll a' Mhadaidh. The stream which flows down Gleann na Muice, a tributary of the Gruinard River, forms the south-eastern boundary of the district.

Though most of the gneiss-ground is here comparatively low, it is generally rough and rugged, forming low, steep, rocky hills, somewhat rounded in outline, but usually free from glacial drift, with deep intervening hollows, not seldom occupied by fresh-water lochs. The general types of rock in this district agree in character with these described in the previous chapters. The prevailing type is a coarsely crystalline, grey, acid gneiss,

* By the late William Gunn, with notes by B. N. Peach, J. Horne, C. T. Clough, and E. Greenly. The district described in this chapter is shown on Sheets 91, 92, and 101 of the Geological Survey Map of Scotland on the scale of ($\frac{1}{63360}$) one inch to a mile.

generally containing biotite, sometimes also muscovite. In the southern part of the district the foliation is in the main well defined, with a fairly regular W.N.W. or north-west strike and a dip towards north-east. In the northern tracts, however, the foliation is often very rude and irregular, and the strike exceedingly variable. Often the gneiss is of a massive character, and in places merges into granite, with no trace of foliation. It is there that the largest basic and ultra-basic inclusions occur.

The gneiss generally presents many knots and lenticles, as well as large inclusions of a basic character, both massive and foliated. In a few places it contains large masses of peridotite or serpentine, pyroxenite and hornblendite, as well as pyroxene granulite, as in the ground to the north already described. It is traversed by numerous epidiorite dykes trending generally towards north-west or W.N.W. In the northern tracts these dykes are generally massive, while towards the south many of them have been wholly or partly converted into hornblende-schist. That they are not all of one age is proved by the crossing of one set by another. Another series of dykes of a green colour, weathering into rounded forms containing much biotite, are less acid than the epidiorites and more irregular in their course, which approaches more nearly to an east and west direction. They are cut through by the epidiorite dykes, and are therefore of older date.

To the east of the Gruinard River there lie bands of a finer-grained granulitic, regularly foliated gneiss containing abundance of white mica, and numerous quartz-veins which are not common in the cruder gneiss. The most important of these bands has a width, in places, of more than a hundred yards, and can be traced for more than a mile in a south-east direction. It displays a vertical foliation, and may be regarded as the result of the shearing movement which has also affected certain dykes, converting them into hornblende-schist.

Connected with the gneiss of this district a remarkable band of rocks of somewhat doubtful origin, but possibly sedimentary, stretches from near Beinn Dearg Bheag to Loch na Uidhe (one mile and a half S.S.W. of Little Gruinard), a distance of seven miles, with a width, in some places, of 200 to 300 yards. At both ends it apparently disappears under the Torridon Sandstone. It includes quartz-rock and quartz-schist, quartz-hornblende-schist, hornblende-biotite-schist, and garnetiferous amphibolite, as well as fine-grained micaceous gneiss. These rocks are therefore much older in date than the movements which produced the granulitic micaceous gneiss east of the Gruinard River.

ULTRA-BASIC ROCKS OF THE FUNDAMENTAL COMPLEX.

The rocks of this class include masses of serpentine and peridotite, various kinds of hornblende and pyroxenite, as well as knots or lenticles of hornblende and actinolite. The hornblende knots and lenticles are found in many places all over the district, and form one of the characteristic features of the gneiss. They are too small to be noted on the maps, and their general relation to the gneiss may be most conveniently studied in connection with the still more numerous class of basic inclusions into which they imperceptibly pass. The larger ultra-basic masses, however, require a more detailed description. To the east of the Gruinard River these larger masses may be seen at Lochan an Daimh, 1½ miles E.N.E. of Gruinard House, and near the course of the stream which runs to the west of Carn na Beiste; in the Inveriavanie River east of Loch an Fhamhair, and by the side of a small loch 200 yards further north. Other masses occur to the west of Loch an Fhamhair, while a broad band stretches from a point on the Little Gruinard River, 1¼ miles south of the bridge, nearly as far as Loch a' Mhadaidh Mor. Several bosses occur 350 yards west of the last-named loch. One of the most important of the masses lies on the west side of the Little Gruinard River near its mouth; another occurs as far south as Feachaisgean on the Fionn Loch. The rocks of this class are massive in character, usually dark in colour, but sometimes pale grey, brownish, or green.

At Lochan an Daimh, a mile and a half E.N.E. of Gruinard House, a black ultra-basic rock is well exposed from 50 to 100 yards south-west of the lake. It recalls the banded pyroxenites and hornblendites of the neighbourhood of Scourie. One specimen (4459) was found to be rich in hypersthene. Its other principal constituent is hornblende, and it contains, in addition, augite, olivine, and some magnetite. Another sample (4460) of a somewhat different type is remarkable for the amount of olivine it contains, which is far in excess of any other constituent. These dark massive ultra-basic rocks are almost the only examples reported from this district in which olivine occurs in the Fundamental Complex in considerable amount. They may be described as olivine-hornblende-pyroxenites, but the specimen (4460), which contains little or no hornblende, may be called olivine-pyroxenite.

Small masses of ultra-basic rock, which appear at several places in the ground east of the Gruinard River and south of Lochan na Cairill, are mostly dark-coloured pyroxenite or hornblendite, or grey peridotite, but they include such varieties as olivine-augite-rock (wehrlite), and lherzolite. Between the Inveriavanie and Little Gruinard Rivers also several bands and oval masses of peridotite and hornblende-pyroxenite make their appearance, often associated with early basic material.

By far the largest and most important of the ultra-basic masses that form part of the Fundamental Complex in this district lies to the west of the Little Gruinard River near its mouth. Its northern extremity is about 200 yards due south of the summit of the steep road, the spot which goes by the name of the Cadha Beag, and its general course is west of south from this point. The length of the mass is nearly two-thirds of a mile, and the breadth varies from 40 to 170 yards. The mass is mainly composed of one variety of material, a massive dark hornblende-rock, penetrated in places by bands and strings of light-coloured quartz and felspathic material. This acid material has much of the appearance and character of a pegmatite, but is of quite a different age from the rocks usually classed as pegmatites, and is in fact identical with much of the crude acid gneiss of the district. The black hornblendic mass, moveover, is traversed by ordinary pegmatites of the usual character, and is cut by three epidiorite dykes which cross it in a north-west direction. Masses and lumps of hornblende-rock, similar in character to the larger mass, occur in abundance in the surrounding gneiss, which, near the ultra-basic mass, has a vertical foliation, the strike of which is nearly parallel to the longer axis of the latter.

Masses of pale-coloured brown-weathering peridotite-like rock occur in several places on the western side of Loch Fada (two miles south-west of Little Gruinard). The largest of them, nearly 100 yards long, lies more than half a mile from the southern end of the loch, and about 150 yards from the loch side. The peridotite masses seem to occur as "eyes" in the gneiss, in the same manner as the knots of diorite and hornblende.

On the north-east side of Beinn Dearg Bheag, close to the margin of the basic gneiss, where it alternates with strips of acid gneiss, two masses of a very singular rock make their appearance. It is soft, saponaceous, and light coloured, probably composed chiefly of talc or chlorite, together with another light-coloured mineral. Some of it is purple (?penninite), probably from oxidation. The gneiss on each side is of an unusual appearance, probably from the presence in it of some of this peculiar mineral which, however, has not yet been determined.

The only example of pyroxene-granulite observed in the Lewisian Gneiss of this district was obtained from the neighbourhood of Gruinard House. To the south of the little stream which crosses the road near the keeper's house, and close to the east side of the road, there may be seen an oval boss of dark-coloured rock about 50 yards in length. It contains the same pyroxene and hypersthene as the black pyroxenites from Lochan an Daimh, and the presence of garnets makes it resemble the pyroxene-granulites from the Lochinver, Scourie, and other districts. It is a hornblende-pyroxene-granulite.

EARLY BASIC ROCKS OF THE FUNDAMENTAL COMPLEX.

The rocks of this class which contain felspar are more acid than those which have just been described, but their mode of occurrence in the Fundamental Complex is very similar; indeed, the two classes of rocks often occur together, and sometimes pass into one another by almost insensible gradations. The basic rocks include pyroxene-granulites, massive diorites, and amphibolites, the ordinary basic knots both foliated and unfoliated, and larger masses of somewhat the same character as the knots which will be described as basic gneiss. The ordinary basic "knots" are almost universally distributed over the district, and it is not usual to find any considerable section of the gneiss without examples, though in some places they are much more numerous than in others. In comparison with these knots the larger masses of basic gneiss are rare. The principal places where they are found are on the west side of Loch Fada, to the north of Loch a' Mhadaidh Mor (two miles S.S.E. of Little Gruinard), and around Beinn Dearg Bheag, on the south side of Loch na Sheallag, especially east and west of the northern flank of that mountain, where the largest and most numerous examples may be seen. Less important masses lie to the north of Loch Toll an Lochain.

The mass of which the relations are most clearly exposed crops out about ¼ mile E.N.E. from the northern end of Loch Ghiubhsachain (west of Loch na Sheallag), where it forms an irregular oval 350 yards by 250 yards, the longer axis lying north-east. The rock of which it consists is well-foliated and often a rather evenly-banded basic hornblende-gneiss. Some portions are so dark as to be scarcely distinguishable at first sight from the basic dykes, but differences in structure and even in the form and habit of the hornblende become apparent on further examination.

Three leading facts about these early basic rocks deserve notice—(1) their foliation is parallel to that of the acid gneiss; (2) they have a north-east strike; and (3) they are cut by the basic dykes. All round their margins the gneissose foliation bends, so as to conform with them; in no case was any discordance between the two rocks detected. Long strips and lenticles of acid gneiss are included in them and conform to the trend of the basic rock. Their strike is decidedly north-east, or rather somewhat "crescentic": tending to east on the north-eastern extremity, to which the general form of the mass conforms. They seem thus to act like eyes or nuclei of resistance to the general flow of the acid gneiss, whether we regard that as a fluxion or as due to mechanical movements. They would thus appear to be older than the acid gneiss, and therefore the oldest rocks of the district.

Finally, there can be no ambiguity as to the relation between these basic gneisses and the basic dykes, which, even when the composition of the two rocks may be very nearly the same, can be traced straight through them, as uninterruptedly as through the acid gneiss. There is not the smallest indication of their being the source of the dyke material, and a vast interval of time must have elapsed between the two, for the whole gneissose system was complete before the dykes forced their way into it. A specimen, showing the junction of one of the dykes with the foliated diorite, is in the collection at Jermyn Street. The dykes can also be clearly seen to cross the junction of the basic and acid gneisses.

On the east side of Lochan na Bearta (three miles east of Fionn Loch), a narrow zone of gneiss includes some thin subparallel bands of compact yellowish-green epidiorite with long

Granulitic Gneiss with quartz veins in secondary shear zone in Lewisian Gneiss. Duart Beg, $1\frac{1}{4}$ miles south of Badcall Bay, near Scourie, Sutherlandshire.

slender prisms of black actinolite. The zone extends for about a quarter of a mile in a south-west direction, and varies up to twelve yards in width. Some of the actinolites are nearly an inch long, and all are large in comparison to the other constituents of the rock (5110).

Some three hundred yards north-west of Loch a' Mhadaidh Mor a band of basic gneiss, 60 yards in width, and crescentic in shape, seems to form a great part of the circumference of a circle, of which the massive diorite described below constitutes the centre. The rock is fairly-well foliated, and is bounded on either side by a grey very acid gneiss. Two massive basic dykes, trending north-west, cut this basic band in a marked manner at a considerable angle, and also cut the foliation of the adjoining gneiss which is parallel to the edge of the basic band. Other masses of basic gneiss or foliated diorite are found on the west side of Loch Fada, some of which are in association with the ultra-basic rocks already noticed.

Among a mass of more basic knots, a beautiful diorite, quite unfoliated in parts, occurs as a lenticle east of Loch Ghiubhsachain. Another coarse massive diorite, very fresh in aspect and with large white felspars, has been referred to above. It shows itself about 500 yards to the north-west of Loch a' Mhadaidh Mor, has an oval outline, and measures about 130 yards in length and 75 in breadth. It does not appear to be intrusive in the gneiss, but rather to be one of the numerous "eyes" of early basic material, older than the acid gneiss which surrounds it, though in character it differs somewhat from that of the usual knots. Other large oval masses of basic rock occur in the gneiss to the south-west of Creag na Sgoinne, five miles south-east of Little Gruinard.

The leading feature of the Fundamental Complex in this district may be regarded as the extraordinary abundance of the knots of basic material included in the gneiss. These inclusions are scarcely ever quite absent for many yards at a time, but are apt to occur sporadically in groups. Their longer axes are usually parallel to the strike of the gneiss. In shape they are sometimes oval, sometimes sigmoidal. As the oval form only occurs in the massive gneiss, it has been supposed that the sigmoids are due to drawing out of the original ovals in general movements of the rock. But the sigmoids also occur in very massive gneiss. Where the gneiss is thinly foliated, the knots become more scarce, or even disappear.

These conspicuous and abundant inclusions consist for the most part of a dark hornblendic rock, often not distinctly foliated, and usually not very coarse. There is often, indeed, no striking external difference between them and the material of the dykes. They are of all sizes from mere little kernels or groups of hornblende-crystals up to lenticles 200 to 300 feet long. Very often they occur as confused aggregates or irregular lumps. Some of them are composed of a beautiful broad-bladed hornblende, with scarcely any felspar. Some are epidotic. They may be regarded either as products of segregation, in common with the acid gneiss from an intermediate magma, or as included fragments of an older rock-system, caught up in great intrusions of acid gneiss which now forms the bulk of this region. The larger knots, containing felspar, are sometimes faintly banded, and connect this type of rock with the basic gneisses above described. They can be shown to be cut by the dykes, as clearly as is the basic gneiss.

Around the Ordnance Station on Creag-Mheall Beag, two miles north-west from Loch na Sheallag, the black basic eyes are so numerous and so liable to decomposition that large potholes have been formed in the crude gneiss, both on horizontal surfaces and on steep craggy faces, by the decay and weathering out of the basic lumps, which, here and in most of the places to be still mentioned, are formed of a massive unfoliated rock, enclosed in a crude acid gneiss of a pegmatitic character. One of the finest sections in which these features are displayed is exposed 600 yards to the north-west of Loch an Fhamhair, about a mile and a half from Creag Mheall Beag, where a cliff, 50 to 60 feet high and 100 feet long, is crowded with basic eyes. Another fine section of a similar kind may be seen about 600 yards due west of the same loch. Characteristic examples are also common in the neighbourhood of the Cadha Beag, to the south of Second Coast, and east of the Gruinard River to the north of Lochan na Cairill. In various places the basic material collected in knots and lenticles appears to form as much as one-half of the bulk of the rock.

To the north of Loch na Sheallag, and between it and Loch an Eich Dhuibh, besides basic knots like those above described, there occur others formed of a foliated rock, which may be called a basic gneiss. The foliation of these lumps is very erratic, and has apparently no connection with that of the adjacent gneiss, though sometimes there may be no great discordance between them. In these cases it would appear that an earlier foliated basic rock has been caught up, broken into fragments, and subsequently enclosed in a coarse acid intrusive rock of a pegmatitic character. This case is analogous to that of the large masses of basic gneiss, and of ultra-basic rock already noticed from this district. Inclusions of gneissose rock, possibly of a somewhat different type from any yet mentioned, occur in the neighbourhood of Loch Ghiubhsachain. Such gneissose knots, though comparatively rare, are important from a theoretical point of view. They are usually lenticles of biotite-gneiss, from a foot to three feet long, included in the massive gneiss in the same manner as the basic knots, and they generally occur among groups of the latter. The gneiss of the knots possesses a decidedly different character from any of the gneiss of the country, inasmuch as it has more biotite, contains epidote, and is usually more distinctly foliated. Often this foliation coincides with the long axes of the lenticles, and therefore parallel to the foliation of the surrounding gneiss; but in several cases, the foliation of the lenticles has been observed to lie across the longer axis, and to be in complete and striking discordance with that of the massive acid gneiss which surrounds it. These facts appear to indicate that the knots and lenticles are true inclusions in an igneous magma.

THE ACID PORTION OF THE FUNDAMENTAL COMPLEX.

Though it has been found convenient for purposes of description to divide the area south of Gruinard Bay into two portions, the gneiss cannot be said to present distinct characters in each of them. In both tracts it is marked by the presence of biotite. Muscovite-biotite-gneiss, however, appears to be more common in the north, where the foliation and strike are very irregular. In the southern part, on the other hand, the foliation is fairly-well defined, and shows a general strike to W.N.W. or north-west. The quartz-hornblende band that stretches from Loch na' h Uidhe, about a mile and a half above the mouth of the Little Gruinard River, to the northern end of Loch Ghiubhsachain, on the west side of Loch na Sheallag, forms a convenient boundary between the two portions. South of that band the regularly-dipping gneiss forms a tract from 2½ to 3 miles in width, the greater breadth being west of the Little Gruinard River. In this part of the strip at a few places the foliation for some distance is vertical, but in general the strike remains between north-west and W.N.W., with a steep dip to N.N.E. or north-east.

Everywhere the gneiss is fairly uniform in character. It is a coarse grey acid biotite-gneiss, containing the eyes or lenticles of basic material above described. Sometimes, as already remarked, the basic portions weather out, producing a pitted surface. In some places, where large felspars have been developed, the rock passes into a variety of augen-gneiss, as north of the Fionn Loch, on the west side of Loch Mhic 'Ille Riabhaich, near its northern and southern ends, about a mile further west. Coarse augen-gneiss also occurs quarter of a mile S.S.E., and two-thirds of a mile east of Loch an Iasgair (three and a half miles south of Little Gruinard). In various places gneiss of a very crude character appears to be a kind of mixture of early pegmatite with basic material. Between Loch Ghuibhsachain and the northern end of the Fionn Loch the grey gneiss shows its typical characters. It is a massive acid rock, mainly composed of quartz and felspar, generally coarse in character, and sometimes very much so, usually containing biotite, sometimes also white mica. It displays large individuals of orthoclase, like that of the pegmatite veins, which in some places forms strings and irregular groups. Almost everywhere the characteristic kinds of basic or ultra-basic material are to be seen. The foliation dips steeply to the north-east or north-north-east, at angles of 40°-60° increasing to 70°-80° in the northern part, and in a few places becomes vertical.

The planes of foliation, which are often convoluted, are not better marked here than in a foliated granite, and the rock will break in any direction. In places this gneiss resembles a type of rock which has been regarded as derived from the incorporation of pegmatite on a large scale; in fact, one specimen from a crag east of Loch Toll a' Mhadaidh has actually been described as a pegmatite (4660), and another specimen from the north end of the same crag (4661) as a muscovite-biotite-gneiss.

Grey acid gneiss, with scattered flakes of biotite, or biotite and muscovite, and abundant small knots and lenticles of biotite and hornblende, forms the predominant rock of the early complex near the south edge of the tract between Feachaisgean (Fionn Loch) and the Lochan Feith. The early banding elsewhere traceable as having been in existence before the intrusion of the basic dykes is here often very obscure, and in some places there may be room for doubt whether such a banding ever existed. The later foliation, however, corresponding to that of the basic dykes is generally strongly developed. It usually strikes W.N.W., and dips steeply in a N.N.E. direction, and parallel to the axial planes of many folds which affect the earlier banding. Prominent "augen" of felspar, which occur in the gneiss in some places, are particularly well seen in a crag about half a mile south-west of Lochan Cnapach (three miles east of Fionn Loch).

Muscovite-biotite-gneiss is typically developed in the neighbourhood of the Cadha Beag between a quarter and half a mile west of the bridge over the Little Gruinard River. It is a coarse grey acid gneiss, with the usual abundant inclusions of basic material. In some places the rock is well foliated, in others where no foliation is apparent the rock really becomes a granite in structure (5509). A similar rock (5515) appears at a place half a mile W.N.W. of Loch an Fhamhair (one and a half miles south-east of Little Gruinard). Other rocks of this type occur on the west side of the narrows of Loch a' Mhadaidh Mor, and in a slack 600 yards north-west of Loch an Fhamhair (5513).

Throughout the northern part of the Gruinard district, at many places besides those here mentioned, the gneiss is of so massive a character, with little or no definite foliation, that it becomes granitic in structure as well as in composition. From this condition stages can be recognised wherein a faint foliation appears in the arrangement of the acid and basic material on a large scale, though not traceable in a hand specimen. A further stage of differentiation is presented by the foliation of the acid material round the basic and ultra-basic masses or lenticles, but this arrangement has no one definite direction. Where the basic or ultra-basic mass is of considerable size, the foliation in the gneiss is more or less parallel to its sides, and extends for some distance, so as to give rise to a well-defined strike over a limited area. At the Cadha Beag, for example, where a large ultra-basic mass stretches for half a mile in a north-east direction, the strike of the contiguous gneiss runs in the same direction the whole of the distance. In spite of such local examples, the strike of the gneiss throughout the northern part of the district is much more irregular than in the southern. Only at a few localities, as near Second Coast, to the north of Fisherfield, and in the neighbourhood of Mungasdale (one mile N.N.E. of Gruinard House), can a fairly regular north-west strike be observed. The foliation planes are usually vertical, and their strike often trends towards the E.N.E. or north-east. This apparently abnormal direction may have been here the original arrangement of the early foliation, as is still the case in the district south of Scourie. The large basic and ultra-basic masses present their greatest length in this direction, and there seems to be some evidence, apart from that of these masses, that the general strike of the gneiss was at first E.N.E. or north-east. No difference of character, however, can be traced between the gneiss having this strike and that which strikes north-west. Both rocks are of the same coarse type, and the two directions of strike are not confined to definite areas but alternate in an irregular manner over a large extent of country. Possibly the two foliations may have been produced at the same time, the difference in direction being due to undulations or foldings of one original foliation.

Further evidence of variation in the strike of the gneiss may be observed in the ground on the north side of the lower part of Loch na Sheallag, where two directions in the foliation have been traced at right angles to one another, neither direction being predominant. Again, in the areas south of Loch an Eich Duibh, and between that loch and Loch na Sheallag, the coarse grey acid gneiss shows a poor and irregular foliation, which, though often very obscure, may be found striking in some places north-west, and in others east or north-east. The gneiss contains here many inclusions of foliated and unfoliated hornblende or actinolite, as well as several patches of fine well-foliated basic gneiss, which may be seen to be fragments of a larger mass. On the fine exposures of gneiss along the Cadha Beag road to the west of the foot of the Little Gruinard River, with their abundant basic and ultra-basic inclusions, to which reference has already been made, light seems to be thrown upon the actual process of manufacture of the gneiss. Broad bands of quartzo-felspathic material are there seen to surround and irregularly enclose knots and masses of basic material. It appears as if the gneiss as there displayed consists of masses of diorite and hornblende, which have been interpenetrated by a later acid rock of a pegmatitic character. Plates VI., VII., VIII., and XIII. represent some of the structures of the gneiss in this district.

Between the northern end of the gneiss area at Mungasdale, on the east side of Gruinard Bay, and Enard Bay, a distance of 12 miles, a number of small inliers or bosses of gneiss project through the lower beds of the Torridon Sandstone. They all lie on the eastern side of a large fault, which is believed to cross the mouths of Loch Broom and Little Loch Broom, and to have a downthrow to the west of several thousand feet. Six of these inliers lie to the east of Achnahaird Bay, four in the neighbourhood of Achiltibuie (Baden Bay), several on the Horse Island and Carn nan Sgeir, and the rest near the entrance of Little Loch Broom.

In most of these places the prevalent rock is a coarse hornblendic gneiss, more nearly allied in character to that of the Loch Inver district than to that of Gruinard. It is often of a pink colour, or reddened, as if by staining due to the former covering of Torridon Sandstone. In the Achnahaird Bay inliers, which are small and irregular in outline, the strike of the foliation is fairly regular to north-west, the dip being sometimes as low as 30° or 40°.

Three of the inliers near Achiltibuie occur on the shore. The most northerly of them is composed of coarse grey hornblendic gneiss, the foliation of which dips northward. The ground here is crossed by several lines of fault and crush, embraces some small outliers of Torridon Sandstone, and is bounded on the south by Triassic conglomerate. The most interesting of the inliers is that which lies to the east of Achiltibuie. It forms a kind of dome-shaped mass of higher ground, against which the Torridon Sandstone was deposited, and consists internally of a denuded syncline of gneiss, partly overlapped by the Torridon Sandstone. The greater part of it seems to be occupied by a mass of dark green garnetiferous hornblendite, which forms the centre and highest part of the basin, while round this nucleus two bands of grey acid gneiss with hornblende crop out, concentric on the south and west, but apparently coalescing on the east side. The foliation of the gneiss and the hornblendite has a general dip inwards, at angles varying from 40° to 50° on the west, south, and east sides, rising to 60°, 70°, or more on the north. It thus appears that the ultra-basic core acts as a large eye, and the foliation in the gneiss is parallel to its edge. In the northern part of the outlier an epidiorite dyke appears to cut the foliation of both gneiss and hornblendite, but is only seen in three isolated exposures. The most prominent exposure of rock rises at a point 350 yards north-east of the Inn, where a vein or thin dyke of sandstone, one to two inches wide, doubtless connected with the Torridonian series, passes downwards into the gneiss at least 20 feet.

The gneiss of Meall nan Gabhar and the north end of Horse Island, as well as the rocky islets of the Carn nan Sgeir group, is a coarse grey acid rock, with occasional masses and lumps of hornblendic material. The strike of the foliation is generally from W.N.W. to north-west.

The most remarkable of the bands of fine flaggy micaceous granulitic gneiss, with vertical foliation, previously referred to (p. 173), as due to later shear movements, extends south-east, from a point on the shore about ½ mile to the north of Gruinard House, and can be followed inland in a south-easterly direction nearly to the edge of the Torridon Sandstone, north-east of Carn na Beiste, a distance of about two miles and a half. A similar band, in the same line and probably due to the same line of movement, occurs south of Craigour. Several basic dykes that have been isolated in this zone of movement have been sheared and converted into hornblende-schist.

About 30 yards north of the highest part of the Cadha Beag road a band of fine-grained gneiss, which strikes vertically north-west, can be traced in that direction for 200 yards or more. Another band of sheared gneiss, east of the Inveriavanie River, between Carn Lochain Duibh and Lochan Guibhais (south-east of Little Gruinard), has likewise been much affected by subsequent movements. It has been shifted to and fro by several small faults, and the granulitic gneiss, together with its intrusive dykes, has been much folded after being sheared. These intense mechanical movements may account for the rapid thickening and thinning of the dykes in this tract and for their erratic courses. A further example of granulitisation may be cited from near Loch Ghiubhsachain (west of Loch na Sheallag), where some narrow vertical zones of a micaceous and schistose granulitic gneiss can be traced, characterised by white silvery micas. Where such a zone (as east of Beinn Dearg Bheag) passes through the basic gneiss a feathery hornblende-schist has been produced. A short distance further to the north-west, nearly one mile south-east of Guisachan, another zone appears in which the coarser gneiss has undoubtedly been sheared. Thin bands of gneiss rendered fissile in this way are not at all uncommon in the southern part of the Gruinard district, especially along the dykes which have been foliated in whole or in part.

These illustrations of the production of granulitic gneiss and hornblende-schist parallel or nearly so to the general north-west direction of the numerous dykes are precisely similar to those already described from the Scourie district and elsewhere. Of the other and probably later lines of movement in that district, which have had a nearly east course, and have powerfully affected the dykes along their course, examples have been obtained in the present district. One which occurs east of the Gruinard River, 100 yards south of Carn nam Buailtean, can be traced for more than half a mile in a westerly direction, crossing several dykes which are bent out of their course and foliated, just as at Scourie. The most marked effect of the movement is seen half a mile a little south of west from the last-named place, where a coarse massive dyke, some 50 yards wide with a north-westerly trend, has been bent so as to run east and west, and has been attenuated and converted into hornblende-schist.

INTRUSIVE DYKES OF PRE-TORRIDONIAN AGE.

Three different varieties of intrusive dykes make their appearance in the Lewisian gneiss of the Gruinard district. Of these the most important and numerous consist of epidiorite, either massive or in the form of hornblende-schist. A second type is represented by a considerable number of soft green dykes, somewhat irregular in character and containing abundant mica. These are for the most part older than the epidiorite dykes. In the field they weather somewhat like ultra-basic rocks, and appear to be less acid than the ordinary basic type. The third type is ultra-basic in composition, of which only a single example has been met with near the southern borders of this district, unless we include in this class a hornblende-dyke, with very little felspar, which occurs to the south of Lochan Dubh (two and a half miles S.S.E. of Little Gruinard).

(1) The ordinary basic dykes, as will be seen from the map, though numerous, are not evenly distributed over the district. Between the north-east termination of the Fionn Loch and Beinn a' Chaisgein Beag they occupy nearly as much ground as the gneiss, while, on the other hand, there are belts, such as the ground immediately south-west from Creag na Sgoinne (five miles south-east of Little Gruinard), where few are to be seen. It must be remembered, however, that some of the areas, where few dykes appear on the map, are obscured by drift.

The individual dykes vary much in width. While some are too small to be shown on the map, others measure upwards of 100 yards across. Some irregular examples in the area north-east of Creag Mheall Beag reach to between 130 and 170 yards in width. South of Lochan Dubh two dykes have each a breadth of about 130 yards, and, after decreasing in size to the eastward, they again swell out, and unite into one great mass measuring more than 200 yards across. As in other districts the dykes often project at the surface and form prominent features, while they occasionally weather into hollows or slacks, as near Loch an Iasgair, three and a half miles S.S.W. of Little Gruinard.

Adjacent dykes which run nearly in the same direction are often found to coalesce. The reverse process also occurs, a single intrusion splitting up into several separate dykes, as may be seen near the north end of the Fionn Loch, east of Loch Toll a' Mhadaidh, and immediately south-east of Guisachan (four miles south-east of Little Gruinard). In these cases the dykes are all presumably of the same age, but in a few cases two sets of dykes appear, one of which is of earlier date than the other. West of Carn na Beiste what appears at first sight to be a large dyke giving off smaller branches is found, on examination, to be a case of a large dyke of later date crossing several smaller and earlier intrusions. Again, on the north side of Loch a' Mhadaidh Mor, a striking example appears of the intersection of several north-west dykes by a large east and west dyke of later date.

The intrusive character of the dykes is best exhibited in the neighbourhood of some of the larger basic and ultra-basic masses, such as those at the Cadha Beag and near Beinn Dearg Bheag, where the dykes cut the foliation of the gneiss nearly at right angles.

In the northern part of the district, for a width of five miles or more, all the dykes are massive epidiorites, except in those few narrow zones of shearing movement previously described, where they have been converted into hornblende-schist. In this area the dykes are vertical. South, however, of the quartz-hornblende zone they often occur wholly or partly in the form of hornblende-schist, and have a hade to the north-east of about 40°-50°, nearly parallel to the prominent foliation in the gneiss, as may be clearly seen between Loch na Moine Buige and Loch Fada, S.S.W. of Little Gruinard.

Between Loch Ghiubhsachain and Loch na Sheallag, the basic dykes, with the usual north-west trend, occur in belts or sheaves. On the south-west of Creag Mheall Mhor smaller dykes are in two cases seen to coalesce upwards and form one large intrusion. The chilled edges of these dykes, now converted into fine-grained hornblende-schist, can be distinctly traced through the basic masses, even when these most resemble the average texture of the dyke. The large dyke east of Loch Toll a' Mhadaidh is completely foliated throughout—a change not usually to be seen in the larger dykes of this area, and all the more noticeable here as the surrounding gneiss does not seem to show any sign of later movement.

A remarkable dyke in the Beinn Dearg belt south-east of Loch Ghiubhsachain (4666), which differs decidedly from its neighbours, though it appears to unite with them, is more basic in composition even than the "green" dykes; yet its marginal parts appear to be ordinary hornblende-schist.

A large dyke of an unusual type occurs on the west side of the Little Gruinard River, crossing the southern part of Loch Fada, and extending E.S.E. past Lochain Cnapach. It is traceable for at least two miles, and throughout the whole of its course is a coarse-grained rock, often foliated throughout. It appears to be much more acid than the ordinary epidiorite dykes, as very few of these contain free quartz. Specimens of this dyke from a place 500 yards south-west of Loch nan Eun consist of rudely foliated hornblende and felspar, with quartz, biotite, and garnet.

Masses of epidiorite which, although few of them can be traced continuously as dykes, are probably of an intrusive character, occur in the moved gneiss above the thrust-plane in the neighbourhood of Ullapool, along the Ullapool River below Loch Achall, at Corry Point, and on the other side of Loch Broom near Loggie. Four specimens of dykes or dyke-like masses from the thrust gneiss area on the Ullapool River below Loch Achall (2089, 3067, 3068, 4885) are described as epidiorites. The rock is dark and compact and traversed by thin veins of epidosite. An epidiorite, more dyke-like in form than that described above, occurs on the north side of the river close to the main thrust. It will be referred to in connection with the earth-movements. (Chap. XXXVI.)

A little north-east of Beinn a' Chaisgein Mor a set of foliated dykes contain extremely abundant inclusions of a pale-grey quartzose gneiss. These inclusions are generally persistent and often so abundant that the dykes containing them can be readily distinguished in the field from the neighbouring intrusions and can be followed over the ground. From the evidence obtained in the field, it seems probable that the dykes in the area north-east of Beinn a' Chaisgein Mor are not all of the same age, those with inclusions appearing in most cases to be earlier than the neighbouring dykes without inclusions; though at one place on the west side of a small burn, two-thirds of a mile north of the top of Beinn a' Chaisgein Mor, an apparent exception is found where a dyke with inclusions occurs within, and is presumably later than another coarser dyke of hornblende-biotite-schist. About half a mile south of Lochan na Bearta, a group of four parallel dykes with inclusions is crossed by other dykes of hornblende-schist which contain no inclusions. A good example of one of these dykes, in which the lenticular inclusions of quartzose gneiss form perhaps half the mass of the dyke, may be seen 300 yards W.N.W. of the north end of Lochan Cnapach. Here the gneiss inclusions appear to have their longer axes more nearly parallel to the direction of dip than to that of the strike of the foliation planes, which resemble in character and composition the gneiss of the surrounding area. The foliation in the quartzose gneiss is often seen to be abruptly truncated at the sides of the inclusions.

Some thin dykes, in which there are indications of porphyritic felspars, occur rather more than a third of a mile north-east of Lochan Cnapach, and half a mile south of west of the outlet of Lochan na Bearta. Dykes with a foliation crossing them in a direction parallel to the modified early banding of the contiguous gneiss are seen in the area surrounding Lochan na Bearta. In some cases the foliation at the margins is nearly parallel to the sides of the dyke, but changes its direction towards the inside. In the dyke-rocks near Lochan na Bearta the stretching lines are generally diagonal to the direction of dip of the planes on which they occur and their upper ends are on the south-east side, but the amount of variation from the direction of dip varies in different places.

A short distance south-east of the outlet of Lochan na Bearta, dykes, now in the form of hornblende-schist, appear to have been folded along axial planes striking north-west, nearly parallel to the general direction of the dykes of the region. At one place the hornblende-schist is associated with a band of mylonised and crushed rock, which also strikes north-west. Other examples of folded dykes are to be seen between the Inveriavanie and Gruinard Rivers, quarter of a mile east of Carn an Lochain Duibh and a little more than half a mile south of Creag Mheall Beag.

(2) The green dykes are most numerous to the south of Creag Mheall Beag and Loch a' Mhadaidh Mor, where they form

prominent features in the landscape. Some of them are coarse-grained and contain large plates of biotite, in others the biotite is less prominent. It will be seen from the map that the course of these dykes is much more irregular, and in a direction more approaching to east and west than that of the epidiorite dykes, and that they are crossed by the latter in several places. The same group of dykes is continued in the ground between the Little Gruinard River and the outlet of Loch na Sheallag. A thick cluster of them occurs about a mile north of Loch Ghiubhsachain, where they have a north-west trend. They are here soft, olive-green rocks, showing plates of green mica, which is especially conspicuous in the coarser parts, and also in segregation spots. Specimens from the margin and centre of a dyke north of Beinn Dearg Bheag are doubtfully referred to the class of amphibolites (4662, 4663).

The dykes of this type are coarse and quite unfoliated in the centre, and not very schistose even at the margins. They have good chilled edges, and also show clear intrusive junctions, proving that they are real dykes and not of the nature of basic knots. They are excessively variable in width, and in this respect are much unlike the ordinary or epidiorite dykes. They are traversed by basic dykes of epidiorite, which present chilled margins where they cut the older intrusions.

(3) Half a mile south of the outlet of Lochan na Bearta a dark-green, foliated, ultra-basic dyke has been traced for about three-quarters of a mile. For most part of its course it closely follows the north-east side of a thick dyke of hornblende-schist, but diverges near its south-east end. The rock being of a more perishable character than the contiguous schists has given rise to a rather conspicuous slack or valley-feature. There is evidence that this intrusion is later in age than the contiguous hornblende-schist. The amount of felspar in the rock is variable, but in the specimen, which has been microscopically examined, it is so small that it seems best to include the dyke in the hornblende series.

As supplementary to the description of the gneiss of the Gruinard district, there falls to be described the peculiar belt of rocks which stretches from Loch na'h Uidhe (one and a half miles S.S.W. of Little Gruinard) to Loch Ghiubhsachain. Its most north-westerly exposure lies close to the north-east end of Loch na'h Uidhe, where bands of quartz-schist and mica-schist may be observed. One of the specimens collected here, an epidotic quartz-hornblende-schist (5505), is a light grey compact rock, traversed by narrow bands containing hornblende. Another specimen (5508), besides abundant epidote, presents also hornblende, biotite (scarce and mostly represented now by chlorite), felspar, and quartz. A third specimen shows much biotite, together with hornblende, felspar, quartz, and iron ores. A fourth variety (5507) contains the same materials as the last, with the addition of garnet, but has quite a different appearance, with more or less rounded patches of garnet projecting as knots

PRE-TORRIDONIAN MOVEMENTS.

Numerous examples of the effects of these movements have been observed in this district, but few of them require particular notice. The faults and crushes usually form distinct topographical features similar to those already noticed in other parts of the Report. An important crush-line, already alluded to, follows the course of Uisge Toll a' Mhadaidh. On its western side the large dykes are considerably shifted to the north. Its effects may be traced for about a mile to the north of Loch a' Mhadaidh Mor. The displacement of basic gneiss, etc., by the fault in this part of its course, has already been noticed. Another powerful crush coincides with the course of the lower part of the Inveriavanie River, and is well seen for more than than 200 yards on the east side, about a mile up the river. Above this point the fault divides, one branch following the course of the stream, the other passing off to the eastward towards Lochan Guibhais. Other faults and crushes are numerous near the lower part of the Inveriavanie River, especially on its eastern side. The most important of these crosses that river in a S.S.W. direction not far from its mouth, and is continued as far as the Little Gruinard River, its course for nearly the whole distance being marked by a conspicuous scar or feature.

A flinty crush, running E.N.E., forms a fine crag half a mile N.N.W. of Carn na Beiste, east of the Gruinard River. Two other features parallel to it but nearer Carn na Beiste have probably a similar origin. Near Lochan na Bearta (three miles east of Fionn Loch) and on the western side of Loch Ghiubhsachan, a good many lines of compact, crushed or partially mylonised rock, accompanied by sharp contortion, have been observed. The material in most of them is of a deeper-red colour than that of the surrounding gneiss, but it sometimes resembles black halleflinta. The general trend of these lines of movement is W.N.W., nearly parallel to that of the basic dykes.

CHAPTER XII.

LOCH MAREE AND GAIRLOCH DISTRICT.*

This district extends from the Fionn Loch, north of Loch Maree, to within three miles of Loch Torridon. Its northern limit is defined by a line running from the head of Gleann na Muice, by the northern slope of Beinn a' Chaisgein Mor, and the north-west branch of Fionn Loch, to Loch an Eilein. Its southern boundary follows the Craig river to its source, and thence east to the south slopes of Ben Dearg. Its length from north to south is about 12 miles, and its greatest breadth about 9 miles.

Most of the rocks to be now described lie west of the ground affected by the post-Cambrian movements, and are included in two areas of approximately equal size, which are separated by a great fault that runs along the basin of Loch Maree and by the south-west side of Loch Ewe. The north-eastern portion may be called the Loch Maree-Carnmore area, and the south-western the Gairloch area. Along the margins of both of these areas the Lewisian gneiss is in most places covered unconformably by the Torridon Sandstone. The boundaries of the formations are of irregular shape, small inliers of gneiss are surrounded by Torridon Sandstone, while outliers of the Sandstone are found within the tracts of gneiss.

In the areas affected by the post-Cambrian movements the Lewisian gneiss reappears in several localities, the most important mass lying north of Kinlochewe. The Loch Maree-Carnmore area measures about ten miles in length and about five in breadth. The rocks are sometimes concealed under wide coverings of drift, particularly at the sides of Fionn Loch. The summits of A' Mhaighden, Beinn Lair, and Beinn a' Chasgein Mor, all of which exceed 2800 feet in height, are covered with drift, though some of their sides form magnificent precipices. These hills lie in the eastern half of the district, and the general elevation decreases in a W.N.W. direction. The Gairloch area is generally rocky, the highest eminences lie towards its south-eastern borders, but no parts formed of Lewisian gneiss exceed 1400 feet in height.

The boundaries of the Lewisian gneiss in this district have been partly determined by lines of fault. The greatest of these

*By C. T. Clough, with notes by B. N. Peach, J. Horne, W. Gunn, and E. Greenly. The district described in this chapter is comprised in Sheets 81, 91, and 92 of the Geological Survey Map of Scotland on the scale of ($\frac{1}{63360}$) one inch to a mile.

dislocations, that of Loch Maree and Loch Ewe, forms the most striking topographical feature of the region. It might seem as if the Lewisian rocks on the north-east side of this fault had been shifted laterally in a south-east direction for a distance of about nine miles. As, however, the pre-Torridon land surface was singularly uneven on both sides of Loch Maree, and consisted of steep mountain-slopes with a pre-Torridon fault between, it is possible that the straight cliffs in which the Archæan rocks now end, both on the north-east side of the Gairloch area and the south-west side of the Loch Maree-Carnmore area, are of pre-Torridonian age, though there have certainly been movements along them in post-Torridonian times. The post-Torridonian fault near the head of Loch Maree seems to be a horizontal displacement along a vertical plane, the Fasagh N.N.E. fault being apparently shifted laterally to Grudie, a distance of nearly three miles in a north-west direction. The plane of this fault is nearly vertical, and a vertical downthrow could not account for its lateral shift.

Between Tollie farm and Loch an Iasgair, to the south-west of Loch Ewe, a fault, partly of pre-Torridon age, runs parallel to the Loch Maree dislocation, and towards the north-west forms the boundary between the gneiss and the Torridon Sandstone. Again, near Dubh Loch, four miles south-east of Gairloch, the most important of a series of north-east faults forms the boundary between the gneiss and the sandstone for more than a mile and a half, but is certainly in part of pre-Torridon age. Lastly, the north-eastern boundary of the gneiss area near Doire, on Loch Maree, and for a mile and a quarter north-west, is probably a post-Torridon fault.

One of the most interesting features in the geology of this district is the occurrence of a group of rocks which resemble altered sediments. They are found in each of the two areas, one prominent belt of them running along the southern edge of the Loch Maree-Carnmore area, and another broad band crossing the Gairloch area in a north-westerly direction. If these rocks are truly of sedimentary origin, they are probably as old as any examples of such deposits of which the stratigraphical position can be approximately determined in the British Isles.

The rocks which constitute the fundamental complex of the Lewisian gneiss cover the greater portion both of the Loch Maree-Carnmore and Gairloch areas. The basic dykes intrusive in that complex are in most places abundant. The acid intrusions are represented by pegmatites, and are here rare or thin, except in the ground between Loch Tollie and Loch Doire na Herrie (three and a half miles E.S.E. of Gairloch), and also near the Dubh Loch of Carnmore.

Wide and comparatively gentle flexures, of pre-Torridon age, and with axial planes striking north-west, have folded the basic dykes in various places—for instance, south-east of Loch Tollie, south-east of Loch nam Buainichean, on Sron a' Choit, on the east side of Loch a' Ghobhainn, half a mile north-east of

Fine grained granulitic Biotite-Gneiss. About ½ mile W.S.W. of Loch Tollie, near the road between Poolewe and Gairloch.

Folais, and near Carnmore. The broad flexure near Tollie is an anticline, with a general south-easterly pitch and a breadth of about two miles: the south-west limb dips steeply south-west or is vertical, while the north-east dips north-east at lower angles. The Carnmore fold is also an anticline of much the same breadth. Between these anticlines comes a compound syncline, which is seen between Beinn Airidh a' Char and Slioch. It is important to notice that these folds do not necessarily indicate the disposition of the rocks of the fundamental complex, for these rocks were in many cases already in a highly contorted condition before these later flexures were developed.

The plateau of Lewisian gneiss under or adjacent to the Torridon Sandstone is often stained red, as near Talladale (south side of Loch Maree), near Druim am Uamh (Gairloch), and on the west side of Meall Imireach (four miles W.N.W. of Poolewe). Dykes or veins of red sandstone or grit, from a quarter of an inch to several yards wide, cross the gneiss in many places. Examples of these may be seen in the Gairloch district by the side of the road half a mile west of the outlet of Loch Bad an Sgalaig, three-quarters of a mile E.S.E. of the outlet of Loch Braigh Horrisdale, on the west side of Meall Aundrary, close to the north side of Loch na' Feithe Mugaich, and on the flanks of Meall Each, near the head of Loch Maree. The material in the dykes is like that of the adjacent Torridon strata, but similar dykes also occur in the Torridon Sandstone.

ROCKS OF THE FUNDAMENTAL COMPLEX.

Ultra-Basic Rocks.—These are in this district represented by hornblendite, biotite-hornblendite, peridotite or impure serpentine, and small bands and lenticles which consist almost wholly of biotite. Many thin bands and lenticles of hornblendite and biotite-hornblendite appear both in the early basic rocks and in the acid gneisses. Besides those in which the hornblende is black microscopically, others are almost entirely composed of needles of pale green actinolite. In some of the thicker black lenticles biotite occurs at the margin and hornblende in the interior.

A pale acid gneiss exposed in a burn about a quarter of a mile north-east of Carnmore Old House encloses various lenticles—the largest measuring ten yards in length—which consist in large part of pale-green actinolite. The outside of each is formed of a dark micaceous sheath, often about a foot wide, in which the biotite flakes are parallel to the adjacent side, while inside comes a rim, usually three or four inches wide, consisting chiefly of actinolite crystals with their long axes crossing it at right angles. In this rim also small spaces may be noticed, sometimes hexagonal in section and probably once occupied by garnet, but now filled with aggregates of brown and green mica. The interior parts of the lenticles consist of large crystals of green actinolite mixed with flakes of white talc (?). These lenticles are of particular interest because they contain scales of graphite more than a quarter of an inch long.

Other masses of ultra-basic rock of considerable size occur on the east side of Loch an Eilein, at the north limit of this district, on Croft Hill, south of Poolewe, and in the hornblende gneiss south of Tollie. These consist chiefly of hornblende rock, sometimes in association with biotite and thin strings of felspar and quartz.

Near the south-east corner of the Gairloch area patches of hornblendite or biotite-hornblendite were observed at the following localities: 1000 yards slightly south of west and half a mile E.S.E. of the west end of Lochan Druim na Fearna, rather more than a quarter of a mile S.S.W., and a third of a mile S.S.W. of Mullach nan Cadhaichean. The rock nearest the last-named locality is thrown into a series of small folds, in the cores of which most of the hornblende appears, while biotite is especially abundant in the limbs.

An exposure of serpentine, about 300 yards long, occurs about three-quarters of a mile south of the head of Loch na h'Oidhche (three and a half miles south of Slattadale, Loch Maree). It has been the source from which many boulders on the south side of Loch a' Bhealaich have been derived. This rock varies considerably in character, the surface tints being pale-grey, bluish-grey, green, or orange. The varieties that weather pale-grey contain many scales of talc (?), sometimes collected into veins, crystals of some ferriferous carbonate, and dark-grey or black fine-grained portions, forming hollows with a rusty surface, which are now composed of decomposition products of some earlier silicate. Some of the greener portions have a rough exterior, and contain stout crystals of decomposed enstatite (?). Most of the rock shows no foliation, but near the western end an obscure foliation dips at steep angles slightly west of south, and near the eastern limit E.N.E. About two-thirds of a mile south of Meall an Tuim Bhuidhe (five miles south of Shieldaig, Loch Gairloch) several lenticular masses of olivine-hornblende-peridotite have been noticed, which weather with an orange crust. In one of them the olivine is fresh and abundant and the hornblende colourless. Three-quarters of a mile north-east of Furnes (on the north side of Loch Maree) an outcrop occurs of an ultra-basic rock of variable composition, partly calcareous, and with portions softer than the finger nail. Some patches in it appear to be mainly composed of serpentine, but they also contain a cleavable mineral—presumably some rhombic pyroxene—from which the serpentine has been formed. Certain parts contain abundant flakes of chlorite and needles of tremolite, others consist almost entirely of crystals of dark-green hornblende. A few streaks of magnetite, about an inch thick, were noticed in one place.

Early Basic Rocks and Hornblende Gneisses.--As a rule, the early basic rocks which form part of the Fundamental Complex are more variable in composition than the basic dykes, and contain more irregular streaks of quartz. In unsheared areas the margins of these basic masses and those of the basic dykes can be readily distinguished, the early basic rocks being so mixed with strings of acid gneiss that they can hardly be separated. This intermixture may perhaps be due, not so much to intrusion after the basic parts were solidified, as to segregation in a viscous magma and to movements in the partially differentiated mass.

Owing to their variability no satisfactory distinction can be drawn, in the field, between the hornblende-gneisses with, and those without quartz. Many of the early basic rocks are massive with only an occasional well-marked foliation. In these types the quartz occurs in thin opalescent strings, winding round eye-shaped masses of dark hornblendic rock, varying in length from a few inches to a few yards. The garnets in this series of rocks vary considerably in abundance and size, but here they are usually much smaller than those found in the Laxford and Kylesku district. Their presence cannot be taken as an indication that the rock in which they occur belongs to the early complex, for garnets abound in many of the basic dykes.

Rocks of the two groups characterised respectively by compact hornblende and a granular structure, and by hornblende in fibrous or other aggregates sometimes occur in the same area without a clear line of division between them. On the west side of Poolewe, and between Poolewe and Ob a' Choir'-uidhe (a bay in the west end of Loch Maree), where a large area of hornblende-gneiss is exposed, a specimen (4187) obtained from near the south end of the mass is referred to the second group, while two others (4992, 4993), from near the north end, are assigned to the first. In the group with compact hornblende and granular structure, the hornblende is supposed by Mr Teall to be original, whereas in the group with aggregates of hornblende it is regarded as derived from an earlier pyroxene. It is possible that in some parts of one great igneous mass the predominant ferro-magnesian constituent may have been hornblende and in others pyroxene, and, after the alteration of the pyroxene, rocks of the two groups might be found in close association. It is necessary, however, to bear in mind that the hornblende in some of the foliated basic dykes is also of the compact type and indistinguishable from that in some of the gneisses. If the foliation in these dykes is a secondary structure produced after the solidification of the rock, the hornblende in them must also be of secondary origin.

As the granulitic hornblende-gneisses have been produced by shearing from the other hornblende-gneisses, it will be most convenient to describe them with their parent rocks. In the Gairloch inlier the largest mass, rich in hornblende, stretches from near Doire, west end of Loch Maree, to Naast (two and a half miles beyond Poolewe)—a distance of six miles—and there are traces of it even as far as Inverasdale (west side of Loch Ewe). Its north-eastern boundary is formed by the great thrust or fault that skirts Loch Maree and Loch Ewe; its south-western margin is not well defined, but near Tollie the breadth of the belt from south-west to north-east is about two miles and a quarter. Near the south-western margin of the basic mass the rock is rather evenly banded, dark hornblendic layers alternating with others of a paler tint. This type seems more common in the south-west limb of the Tollie anticline than anywhere else. On the south-west side of Loch Tollie the mass is more than half a mile broad.

The area embraced by the Tollie anticline is crossed by a series of pre-Torridonian faults and flinty crush-rocks that run in a general S.S.E. direction from about half-way between Loch Tollie and Tollie Bay. On one side of this series of dislocations the rocks somewhat differ from those on the other. On the east side, and particularly east of an imaginary line connecting Ob a' Choir'uidhe and Tollie Bay, a massive diorite is largely exposed, in which there is no clear plane-parallel-foliation, though a rodded or linearly-foliated structure can be recognised. The best sections may be seen on the headland, a mile W.N.W. of Ardlair, Loch Maree, and two-thirds of a mile west, and a mile north-west of this promontory. Most of the rock is paler than the basic dykes, and it contains many strings and rods of opalescent quartz. On the headland the felspar granules, many of which show distinct striation, are about the size of a mustard seed. The hornblende is often in grains of about the same size as the felspar, but rather less abundant. Where streaks of quartz occur, they generally lie close to others which consist almost entirely of hornblende, Where the rock is foliated, the paler folia are composed to a large extent of quartz, while the others are chiefly of hornblende. The folia often strike north-west, and are nearly vertical, but they are not generally granulitic. It is worthy of note that most of the basic dykes which traverse these early rocks have a similar trend and rarely display foliation. Some of them cut the foliation planes of the early basic material, and it is evident that the latter rock was foliated and often in a vertical position before the dykes were intruded.

Specimen 4187, one of the rodded diorite-like rocks from the headland above referred to, shows no continuous parallel folia, but the hornblende and felspar have their long axes in one direction. In transverse sections no parallelism in the arrangement of the constituents can be perceived. The most conspicuous constituent under the microscope is a striated felspar, which occurs in irregular grains often of considerable size. The hornblende occurs in irregular patches, consisting of small grains and imperfect crystals associated with quartz.

About two-thirds of a mile south-east of the summit of Creag Mhor Thollie (two and a half miles S.S.E. of Poolewe), on an almost flat surface, many pieces of well-banded hornblende-gneiss may be observed within, or traversed by, a pale more acid gneiss which consists of felspar, hornblende, and occasional quartz. Some of the pieces in the flat surface are more than three feet long, and most of them have rather rounded outlines. The folia in them are sometimes twisted and strike against one another. (Plates X., XI.) A similar brecciated structure also occurs in other parts of the same neighbourhood, and must have been in existence before the intrusion of the basic dykes.

In the early basic rocks, unusually acid and exceptionally basic parts are often found close together. Their association suggests that the banding and irregular mixing of the materials were produced while these were still in a viscous state. It is probable that the conditions under which the various parts of the earlier rocks were formed, or have at some time passed, differed from those which prevailed during, or subsequent to, the intrusion of the basic dykes.

The large basic mass two miles north of Loch Gairloch (Sheet 91), which forms Meall Glac na Daraich, is entirely isolated by unconformable Torridon Sandstone, and no outcrop of gneiss occurs within some miles of it. Consequently its relations to the rest of the gneiss are doubtful, but it probably belongs to the early basic group. In general, it consists of a coarse, massive, light-coloured diorite, which shows little or no trace of foliation, but presents in places prominent divisional planes that dip south-east. A few narrow bands of fine-grained dark rock, which cross the coarser material in various places, are probably intrusive and rather of the nature of sills than of dykes. They seem mostly to trend north-west or W.N.W. and to dip south-west. Narrow zones of fairly well-foliated or sheared rock are found in a few places on the same hill, which run in the main in the same direction as the finer bands just described, and sometimes coincide with them.

In the promontory of Ard Ialltaig, one mile south of Gairloch, a considerable amount of dark hornblendic rock is irregularly mixed with a more quartzose variety. In a central band, more than a quarter of a mile broad, the quartzose type contains broad streaks of opalescent quartz, many garnets, and large scattered crystals of hornblende. Small "augen" of felspar are occasionally found. The dark and the pale parts sometimes occur in parallel folia, but more commonly the former appear as lumps round which the latter sweep. The central band is crossed by many thin zones of sheared granulitic gneiss, most of which are vertical and strike N.N.W. On either side of this band there are also sheared areas of some width. North-east of it, where the rocks are most deformed and finely granulitic, the gneisses are flaggy, vertical, and strike N.N.W., and are difficult to distinguish from the schists on their north-east side, which are supposed to represent altered sediments. Specimen 4342 was taken as an example of one of the sheared zones within the central band. In the field, the obscure or irregularly arranged parts at the side of this zone are seen to be gradually dragged into parallelism, in a vertical position, so as to form the schistose material from which the specimen was taken. This specimen is a dark fine-grained rock which shows on the weathered face some white spots, about the size of peas, with curved tail-like processes. Under the microscope there can be seen various rounded grains of a mineral which is probably scapolite. The white spots are formed of more or less granulitic felspar, and the matrix consists of colourless microcrystalline material, with small flakes of pale-brown mica. In the section, 5128, representing the massive rock at the side of the shear zone from which the scapolite schist was procured, no scapolite was found.

Excellent sections of early basic rocks occur about half a mile west, and half a mile south-west, of Mullach nan Cadhaichean. Some of the larger masses contain pieces of garnet varying in size from a pea to a hazel nut, and edged with rims composed of grains of white felspar.

North of Loch Maree, between Ben Slioch and the Folais Burn, hornblendic gneiss appears, and near the centre of the area various broad bands of hornblende-schist have been noted, the age of which is uncertain. An evenly banded variety with epidote often appears near the Letterewe limestone and on the north-east side of the thick hornblende-schist which accompanies this limestone.

Early basic rocks are also met with near the crag tops half a mile north-east of Carnmore, and on the west and north-west sides of Beinn a' Chaisgein Mor, to the north-east of Fionn Loch. Near the latter locality the basic material is much mixed with a pale-grey acid gneiss, either in broad masses or in thin irregular strings, which may cross the foliation of the basic rock. Large basic lumps are also enclosed in the acid gneiss. Most of the basic rock consists of hornblende-schist like that of the later dykes. The felspar is generally subordinate to the hornblende and in smaller grains. In some places the hornblende-schist and the acid gneiss are crossed by a second foliation which strikes W.N.W. parallel to the axial planes of various sharp folds. There seems no clear difference in structure between the hornblende-schist in which the hornblendes are parallel to the second foliation and that in which they are parallel to the broad banding.

Muscovite Biotite Gneisses.—Perhaps the commonest rock in the early complex is a somewhat acid gneiss, carrying numerous flakes of black biotite and occasional muscovite. Oligoclase, microcline, and sometimes orthoclase, are also present, but the first-mentioned felspar generally occurs in excess, and occasionally to the exclusion of the others. Quartz is abundant and generally semi-opalescent. The structure is either granitic or granulitic. The types shade into one another, and the more granulitic are found in zones which have been sheared since the intrusion of the basic dykes. Thin lenticles and inclusions of hornblendite, biotite-hornblendite, and hornblende-schist occur in abundance in certain places. This muscovite-biotite-gneiss often contains abundant "augen" composed of felspar, or of felspar with a small proportion of quartz. In three of the specimens that have been sliced the felspar in the "augen" is for the most part microcline or microperthite. In a fourth it is chiefly, if not entirely, oligoclase. The "augen" generally occur somewhat sporadically; in a few places, as, for instance, rather more than a third and nearly half a mile south of the foot of Loch Tollie, thin fairly well-defined bands contain them in special abundance. Thin strings of augen-gneiss occasionally penetrate the early basic rocks, isolating pieces of them and cutting the banding. On the other hand, augen-gneisses are cut by many basic dykes.

Muscovite-biotite-gneiss forms an extensive bare area on the north-east side of the thick hornblende-schist which runs through Meall Fuaraidh, Sithean Mor (east of Gairloch), and Meall Aundrary, between Gairloch and Loch Maree. South-west of the main zone of presumably Archæan sediments in Gairloch it is very prominent, and perhaps, as a rule, is there more rich in felspar eyes than on the north-east side. It occurs in Kerrysdale in association with altered sediments, and sometimes mixed with them in thin parallel bands in a greatly sheared condition; also north-west of Dubh Loch (three and a half miles south-east of Gairloch), where it is traversed by thin bands of hornblende-schist, and again between Shieldaig and Braigh Horrisdale.

The north-west part of the tract of gneiss between Folais and Slioch consists almost wholly of acid augen gneiss, over an area about a mile and a half long from north-west to south-east, and between half and two-thirds of a mile broad. The rock north-east of the Gleann Tulacha and Strathanmore (north-east of Loch Maree) altered sediments, and between Fionn Loch and the Torridon rocks on the west is chiefly biotite-gneiss with felspar "augen." Similar material forms bare tracts near Gorm Loch Mor, on the north-east side of Eilean Fraoch in Fionn Loch, and on the west slopes of Beinn a' Chaisgein Mor.

In many places the gneiss, whether with or without "augen," contains thin subparallel strips of redder tint than the rest, some coarser and others finer in grain than the gneiss in which they occur. Both coarse and fine varieties are well seen in the area about a mile and a third S.S.W. of Beinn Lair (two miles north-east of Letterewe, Loch Maree), where the fine strings generally stand out in relief and weather with smoother surfaces than the rest of the rock. All the strings are truncated by the basic dykes, and must be of older date. They are usually only about an inch thick, but in places so crowded that they form a considerable proportion of the whole rock. Apart from the redder streaks, an early banding, older than the basic dykes, is indicated in some places by variations in the amount of mica, or by thin parallel basic streaks and lenticles, but in many places little or no indication of this structure can be seen.

The matrix in which the "augen" are embedded has in most districts a pale-grey tint, but a red hue prevails for some distance off various lines of crush. In the sheared rocks the quartz chiefly occurs in long folia which frequently sweep round the "augen," but among the less sheared types this mineral projects in an irregular network on weathered faces, and is often opalescent. Most of the "augen" vary from the size of a small pea to that of a walnut, but a third of a mile south-west of Feachaisgean (Fionn Loch), an example of one was seen four inches long and three broad. In the fresh rock these eyes generally appear of a more pink colour than the small felspars, and in most of the larger specimens are composed of more than one felspar individual.

In certain sheared areas numerous thin thrust-like lines occasionally displace the early banding. Some of these perhaps existed before the dykes, though the rocks in which they occur have been subsequently altered in structure. In some exposures about a mile S.S.E. of Feachaisgean various sharp twists in the early banding are accompanied with lines of discordance. These lines are represented by streaks which are not more granulitic than the adjacent bands, and as there is no second foliation parallel to them, it seems probable that they were caused by movements which took place before consolidation.

Inclusions of hornblende-schist, or of dark well-foliated hornblende-gneiss, with the folia ending bluntly at the sides, have been noticed in many places, but more numerous than these are small lenticles and streaks of hornblende, biotite-hornblendite, and biotite rock. Round the margins of these lenticles an obscure banding is often indicated by dark micaceous layers, which are crossed by a second foliation, and probably existed before the intrusion of the basic dykes.

In a few places where the shearing has been intense, the felspar augen have been granulitised and pulled out into long streaks, but much more frequently the shearing has gone round these inclusions without much altering them. The exposures on the hillside, a mile E.S.E. of Loch Braigh Horrisdale (south of Shieldaig on Loch Gairloch), show the augen gneiss comparatively unaltered. Here the basic dykes are foliated only in part, and show intrusive characters. Common planes of foliation of secondary origin often traverse both the dykes and the augen gneiss. These secondary planes generally strike north-west, and are parallel to the sides of the dykes, but they sometimes can be traced from the gneiss into the dykes. At the same place in two thin zones of the gneiss the early bands become suddenly vertical, or are sharply contorted along axial planes that strike W.N.W. In these zones the bands are considerably thinned, and the quartz and felspar granules in them become smaller and more elongated—all in one direction.

Rather more than a mile south-west of Loch Braigh Horrisdale a second foliation strikes in the unusual direction of about N.N.E., and thin zones of shearing run north and south. In

Rod-like or mullion structure in Lewisian Gneiss, Poolewe anticline, produced by movements later than the dykes. Half-mile north-east of Meall an Spardain, Poolewe, Ross-shire.

basic dykes and frequently throw them, or even, near the north-east margin of the gneiss area, cut them up into small lenticles.

Most of the gneisses of Meall Riabhach and Smiorasair differ from those in the Regoilachy-Fasagh strip in being much more regularly banded. They are chiefly hard, grey, rather massive gneisses, with not much biotite, and with a lack of lenticular flaky or wavy structures. The gneiss is, as a rule, granitic rather than granulitic, but displays strong indications of cataclastic action in certain parts (4280).

In some places within the plicated area near the Dubh Loch of Carnmore (south-east end of Fionn Loch), as, for instance, near the centre of the anticline, no distinct first nor second foliation can be traced. A little south-west of the centre, on the north-east sides of Gleann Tulacha and Lochan Fada, the gneiss is less massive and shows a foliation that dips S.S.W., often at angles between 30° and 60°, while on the north-east side the general dip is steep, often about 70°, in a north-east direction. An earlier broad banding is, however, not unfrequently observed which is crossed by this second foliation, and it must be remembered that the anticlinal arrangement refers only to the dykes, and the various older structures are now difficult to trace.

While most of the Carnmore gneiss is more granitic than granulitic in texture, it includes a zone in which the foliation is finer than usual, and wherein the structure may be partially granulitic. This zone keeps at the side of the folded and foliated basic dyke which crosses the stream a third of a mile east of Fuar Loch Mor, and can be traced more than five miles. It contains more quartz veins than the adjacent gneiss, and shows various thin thrust-like lines parallel to the dyke. The zone probably acquired its finely foliated character in consequence of movements which took place near the side of the dyke before it was folded into its present form.

Where the felspar "augen" are absent the gneisses near Carnmore bear a resemblance to some of those near Laxford and also to the less fissile rocks in the plicated tract south-east of Loch Tollie, but the rodded structure is not so apparent as in the latter tract. The Loch Tollie and Carnmore areas resemble the ground near Laxford in containing pegmatites later than the foliation of the basic dykes, and the gneisses there have probably at some pre-Torridonian period been covered by a greater thickness of rock than those in adjacent tracts.

The biotite gneiss west of Fionn Loch near the north limit of the district is generally coarse-grained, grey in colour or sometimes pinkish, and with rude or irregular foliation. A low anticline—no doubt a continuation of that at Carnmore—crosses this area in a nearly east and west direction from a little south-west of Eilean Fraoch towards the south end of Loch Ghiuragarstidh (two miles east of Poolewe). The northern dip of the foliation from this central line is at first about 30° or 40°, but it increases in a northward direction, so that near the northern boundary of the area it becomes nearly vertical. The southerly dip from the anticlinal axis is S.S.W. at angles of 30° or 40°. Near Kernsary a number of minor folds are accompanied by thrust-lines along which the rock is finer in grain and more evenly foliated, generally with abundant white mica on the foliation-planes. The gneiss on the north and north-west sides of the Beinn Airidh a' Char (three and a half miles N.N.W. of Letterewe, Loch Maree) hornblende-schist is generally fine in grain and well foliated, often displaying much white mica on the foliation-planes. Some of the specimens which have been sliced show marked signs of cataclastic structure, while others are granulitic.

BASIC DYKES.

Well developed in this district, these dykes display the characteristic features which have been already described in the districts further to the north. In those areas where they have been least altered they strike towards north-west and are nearly vertical, as may be typically seen in the examples on the headland a mile W.N.W. of Ardlair, on the hill-slopes west and south of Meall an Tuim Bhuidhe, and near Braigh Horrisdale. In such situations they partially reveal their original structure and composition. In only two instances, however, both of which came from the headland on Loch Maree nearly opposite Ardlair, has any original pyroxene been detected. A minor amount of alteration is shown where they have passed into epidiorite, but the great majority of them have been so thoroughly altered as to have become hornblende-schist. Occasionally the original igneous structure has not been effaced, as in the case of a dyke near Sithean Mor (2¼ miles south of Gairloch), which has preserved an unusually perfect ophitic grouping of its constituents, and in this respect the dyke resembles many of the Central Highland sills more than the dykes of Scourie*.

Near Meall an Tuim Bhuidhe two dykes have been noted, each almost free from foliation, and presenting large scattered aggregates of felspar in a black fine-grained crystalline matrix. One of them is well seen about half a mile, and the other about 1500 yards, S.S.W. of the hill top. Under the microscope (4193) the edges of the aggregates are seen to be frequently indented by small crystals of hornblende, and to blend with the general mass of the rock, which is a granulitic aggregate of hornblende and felspar. The felspar appears to be an oligoclase-andesine, and contains small inclusions of hornblende.

But even where the material of the dykes has become distinctly schistose, the forms of some of the original minerals may occasionally be detected. Thus, between Loch Garbhaig, north of Ben Slioch, Loch Maree, and the north and south burn, rather more than a mile west of that loch, various bands of hornblende-schist contain somewhat idiomorphic porphyritic forms composed of granules of felspar. One of these bands, about 1000 yards

*This dyke is mentioned again in this chapter.

parts at the side of this zone are seen to be gradually dragged into parallelism, in a vertical position, so as to form the schistose material from which the specimen was taken. This specimen is a dark fine-grained rock which shows on the weathered face some white spots, about the size of peas, with curved tail-like processes. Under the microscope there can be seen various rounded grains of a mineral which is probably scapolite. The white spots are formed of more or less granulitic felspar, and the matrix consists of colourless microcrystalline material, with small flakes of pale-brown mica. In the section, 5128, representing the massive rock at the side of the shear zone from which the scapolite schist was procured, no scapolite was found.

Excellent sections of early basic rocks occur about half a mile west, and half a mile south-west, of Mullach nan Cadhaichean. Some of the larger masses contain pieces of garnet varying in size from a pea to a hazel nut, and edged with rims composed of grains of white felspar.

North of Loch Maree, between Ben Slioch and the Folais Burn, hornblendic gneiss appears, and near the centre of the area various broad bands of hornblende-schist have been noted, the age of which is uncertain. An evenly banded variety with epidote often appears near the Letterewe limestone and on the north-east side of the thick hornblende-schist which accompanies this limestone.

Early basic rocks are also met with near the crag tops half a mile north-east of Carnmore, and on the west and north-west sides of Beinn a' Chaisgein Mor, to the north-east of Fionn Loch. Near the latter locality the basic material is much mixed with a pale-grey acid gneiss, either in broad masses or in thin irregular strings, which may cross the foliation of the basic rock. Large basic lumps are also enclosed in the acid gneiss. Most of the basic rock consists of hornblende-schist like that of the later dykes. The felspar is generally subordinate to the hornblende and in smaller grains. In some places the hornblende-schist and the acid gneiss are crossed by a second foliation which strikes W.N.W. parallel to the axial planes of various sharp folds. There seems no clear difference in structure between the hornblende-schist in which the hornblendes are parallel to the second foliation and that in which they are parallel to the broad banding.

Muscovite Biotite Gneisses.—Perhaps the commonest rock in the early complex is a somewhat acid gneiss, carrying numerous flakes of black biotite and occasional muscovite. Oligoclase, microcline, and sometimes orthoclase, are also present, but the first-mentioned felspar generally occurs in excess, and occasionally to the exclusion of the others. Quartz is abundant and generally semi-opalescent. The structure is either granitic or granulitic. The types shade into one another, and the more granulitic are found in zones which have been sheared since the intrusion of the basic dykes. Thin lenticles and inclusions of hornblendite, biotite-hornblendite, and hornblende-schist occur in abundance in certain places. This muscovite-biotite-gneiss often contains abundant "augen" composed of felspar, or of felspar with a small proportion of quartz. In three of the specimens that have been sliced the felspar in the "augen" is for the most part microcline or microperthite. In a fourth it is chiefly, if not entirely, oligoclase. The "augen" generally occur somewhat sporadically; in a few places, as, for instance, rather more than a third and nearly half a mile south of the foot of Loch Tollie, thin fairly well-defined bands contain them in special abundance. Thin strings of augen-gneiss occasionally penetrate the early basic rocks, isolating pieces of them and cutting the banding. On the other hand, augen-gneisses are cut by many basic dykes.

Muscovite-biotite-gneiss forms an extensive bare area on the north-east side of the thick hornblende-schist which runs through Meall Fuaraidh, Sithean Mor (east of Gairloch), and Meall Aundrary, between Gairloch and Loch Maree. South-west of the main zone of presumably Archæan sediments in Gairloch it is very prominent, and perhaps, as a rule, is there more rich in felspar eyes than on the north-east side. It occurs in Kerrysdale in association with altered sediments, and sometimes mixed with them in thin parallel bands in a greatly sheared condition; also north-west of Dubh Loch (three and a half miles south-east of Gairloch), where it is traversed by thin bands of hornblende-schist, and again between Shieldaig and Braigh Horrisdale.

The north-west part of the tract of gneiss between Folais and Slioch consists almost wholly of acid augen gneiss, over an area about a mile and a half long from north-west to south-east, and between half and two-thirds of a mile broad. The rock north-east of the Gleann Tulacha and Strathanmore (north-east of Loch Maree) altered sediments, and between Fionn Loch and the Torridon rocks on the west is chiefly biotite-gneiss with felspar "augen." Similar material forms bare tracts near Gorm Loch Mor, on the north-east side of Eilean Fraoch in Fionn Loch, and on the west slopes of Beinn a' Chaisgein Mor.

In many places the gneiss, whether with or without "augen," contains thin subparallel strips of redder tint than the rest, some coarser and others finer in grain than the gneiss in which they occur. Both coarse and fine varieties are well seen in the area about a mile and a third S.S.W. of Beinn Lair (two miles north-east of Letterewe, Loch Maree), where the fine strings generally stand out in relief and weather with smoother surfaces than the rest of the rock. All the strings are truncated by the basic dykes, and must be of older date. They are usually only about an inch thick, but in places so crowded that they form a considerable proportion of the whole rock. Apart from the redder streaks, an early banding, older than the basic dykes, is indicated in some places by variations in the amount of mica, or by thin parallel basic streaks and lenticles, but in many places little or no indication of this structure can be seen.

The matrix in which the "augen" are embedded has in most districts a pale-grey tint, but a red hue prevails for some distance off various lines of crush. In the sheared rocks the quartz chiefly occurs in long folia which frequently sweep round the "augen," but among the less sheared types this mineral projects in an irregular network on weathered faces, and is often opalescent. Most of the "augen" vary from the size of a small pea to that of a walnut, but a third of a mile south-west of Feachaisgean (Fionn Loch), an example of one was seen four inches long and three broad. In the fresh rock these eyes generally appear of a more pink colour than the small felspars, and in most of the larger specimens are composed of more than one felspar individual.

In certain sheared areas numerous thin thrust-like lines occasionally displace the early banding. Some of these perhaps existed before the dykes, though the rocks in which they occur have been subsequently altered in structure. In some exposures about a mile S.S.E. of Feachaisgean various sharp twists in the early banding are accompanied with lines of discordance. These lines are represented by streaks which are not more granulitic than the adjacent bands, and as there is no second foliation parallel to them, it seems probable that they were caused by movements which took place before consolidation.

Inclusions of hornblende-schist, or of dark well-foliated hornblende-gneiss, with the folia ending bluntly at the sides, have been noticed in many places, but more numerous than these are small lenticles and streaks of hornblende, biotite-hornblendite, and biotite rock. Round the margins of these lenticles an obscure banding is often indicated by dark micaceous layers, which are crossed by a second foliation, and probably existed before the intrusion of the basic dykes.

In a few places where the shearing has been intense, the felspar augen have been granulitised and pulled out into long streaks, but much more frequently the shearing has gone round these inclusions without much altering them. The exposures on the hillside, a mile E.S.E. of Loch Braigh Horrisdale (south of Shieldaig on Loch Gairloch), show the augen gneiss comparatively unaltered. Here the basic dykes are foliated only in part, and show intrusive characters. Common planes of foliation of secondary origin often traverse both the dykes and the augen gneiss. These secondary planes generally strike north-west, and are parallel to the sides of the dykes, but they sometimes can be traced from the gneiss into the dykes. At the same place in two thin zones of the gneiss the early bands become suddenly vertical, or are sharply contorted along axial planes that strike W.N.W. In these zones the bands are considerably thinned, and the quartz and felspar granules in them become smaller and more elongated—all in one direction.

Rather more than a mile south-west of Loch Braigh Horrisdale a second foliation strikes in the unusual direction of about N.N.E., and thin zones of shearing run north and south. In

PLATE XXV.

Rod-like or mullion structure in Lewisian Gneiss, Poolewe anticline, produced by movements later than the dykes. Half-mile north-east of Meall an Spardain, Poolewe, Ross-shire.

the south part of the large inlier on the east side of Allt a' Ghiubhais an occasional second foliation strikes north-east. It is accompanied with contortions along axial planes in this direction. At each of these localities the basic dykes run north-west, and the unusual trend of the second foliation cannot be due to folding of a second foliation which had originally a different direction. In the inlier, three-quarters of a mile east of Loch na h-Uamha (four miles S.S.W. of Shieldaig on Loch Gairloch), and in the area west and south of Meall an Tuim Bhuidhe (five miles south of Shieldaig), parts of the acid gneiss show no distinct early banding nor yet any second foliation, even though the adjoining basic dykes are foliated.

A little north-east of Lochan Druim na Fearna, some fine schists appear, which are supposed to have been formed in part from an acid augen-gneiss. They form a narrow valley which runs north-west from the side of Dubh Loch. Weathering with a yellow colour, they are very micaceous and fissile, and contain many small augen, often about half an inch broad, together with streaks of quartz and felspar. On the north-east side of the valley a much sheared augen-gneiss winds round a large piece of hornblende-gneiss. The latter does not show much alteration, the shearing movement having gone round it. The quartzo-felspathic matrix is finely granulitised, but the felspar-augen are not. Some of the fine granulitic schists with small felspar-augen are mixed with the mica schists at the south-west side of the main zone of the Archæan sediments of Gairloch, from which they can with difficulty be distinguished. Augen schists of this character are well seen in the banks of the Kerry about a quarter of a mile below the large waterfall.

Near the crushes on the north-east side of the thick hornblende-schist, about a mile and a half south-east of Loch Bad an Sgalaig (three miles S.S.E. of Gairloch), the shearing has sometimes gone so far as to transform the large felspar-augen into long lenticles composed of minute granules. These lenticles are red while the surrounding matrix, in consequence of its abundant biotite, appears dark grey. Many of the augen near the mylonised bands on the west side of the burn rather less than a mile north-east of Furnes have also been partially granulitised and deformed.

The gneisses in the narrow strip on the north-east side of Loch Maree, between the promontory near Regoilachy and Fasagh, are medium-grained and show a tolerably well-marked parallel structure of a flaky or lenticular type, but no well-defined banding. Near the loch the structures generally strike north-west and are vertical, but there is evidence every here and there of intense contortion. None of these gneisses are free from strain, though this feature is least marked in those by the loch. As they recede from the loch the gneisses become more and more crushed along lines of dislocation which are nearly vertical and strike north-west and W.N.W. These lines also traverse the basic dykes and frequently throw them, or even, near the north-east margin of the gneiss area, cut them up into small lenticles.

Most of the gneisses of Meall Riabhach and Smiorasair differ from those in the Regoilachy-Fasagh strip in being much more regularly banded. They are chiefly hard, grey, rather massive gneisses, with not much biotite, and with a lack of lenticular flaky or wavy structures. The gneiss is, as a rule, granitic rather than granulitic, but displays strong indications of cataclastic action in certain parts (4280).

In some places within the plicated area near the Dubh Loch of Carnmore (south-east end of Fionn Loch), as, for instance, near the centre of the anticline, no distinct first nor second foliation can be traced. A little south-west of the centre, on the north-east sides of Gleann Tulacha and Lochan Fada, the gneiss is less massive and shows a foliation that dips S.S.W., often at angles between 30° and 60°, while on the north-east side the general dip is steep, often about 70°, in a north-east direction. An earlier broad banding is, however, not unfrequently observed which is crossed by this second foliation, and it must be remembered that the anticlinal arrangement refers only to the dykes, and the various older structures are now difficult to trace.

While most of the Carnmore gneiss is more granitic than granulitic in texture, it includes a zone in which the foliation is finer than usual, and wherein the structure may be partially granulitic. This zone keeps at the side of the folded and foliated basic dyke which crosses the stream a third of a mile east of Fuar Loch Mor, and can be traced more than five miles. It contains more quartz veins than the adjacent gneiss, and shows various thin thrust-like lines parallel to the dyke. The zone probably acquired its finely foliated character in consequence of movements which took place near the side of the dyke before it was folded into its present form.

Where the felspar "augen" are absent the gneisses near Carnmore bear a resemblance to some of those near Laxford and also to the less fissile rocks in the plicated tract south-east of Loch Tollie, but the rodded structure is not so apparent as in the latter tract. The Loch Tollie and Carnmore areas resemble the ground near Laxford in containing pegmatites later than the foliation of the basic dykes, and the gneisses there have probably at some pre-Torridonian period been covered by a greater thickness of rock than those in adjacent tracts.

The biotite gneiss west of Fionn Loch near the north limit of the district is generally coarse-grained, grey in colour or sometimes pinkish, and with rude or irregular foliation. A low anticline—no doubt a continuation of that at Carnmore—crosses this area in a nearly east and west direction from a little south-west of Eilean Fraoch towards the south end of Loch Ghiuragarstidh (two miles east of Poolewe). The northern dip of the foliation from this central line is at first about 30° or 40°, but it increases in a northward direction, so that near the northern boundary of the area it becomes nearly vertical. The southerly dip from the anticlinal axis is S.S.W. at angles of 30° or 40°. Near Kernsary a number of minor folds are accompanied by thrust-lines along which the rock is finer in grain and more evenly foliated, generally with abundant white mica on the foliation-planes. The gneiss on the north and north-west sides of the Beinn Airidh a' Char (three and a half miles N.N.W. of Letterewe, Loch Maree) hornblende-schist is generally fine in grain and well foliated, often displaying much white mica on the foliation-planes. Some of the specimens which have been sliced show marked signs of cataclastic structure, while others are granulitic.

BASIC DYKES.

Well developed in this district, these dykes display the characteristic features which have been already described in the districts further to the north. In those areas where they have been least altered they strike towards north-west and are nearly vertical, as may be typically seen in the examples on the headland a mile W.N.W. of Ardlair, on the hill-slopes west and south of Meall an Tuim Bhuidhe, and near Braigh Horrisdale. In such situations they partially reveal their original structure and composition. In only two instances, however, both of which came from the headland on Loch Maree nearly opposite Ardlair, has any original pyroxene been detected. A minor amount of alteration is shown where they have passed into epidiorite, but the great majority of them have been so thoroughly altered as to have become hornblende-schist. Occasionally the original igneous structure has not been effaced, as in the case of a dyke near Sithean Mor (2¼ miles south of Gairloch), which has preserved an unusually perfect ophitic grouping of its constituents, and in this respect the dyke resembles many of the Central Highland sills more than the dykes of Scourie*.

Near Meall an Tuim Bhuidhe two dykes have been noted, each almost free from foliation, and presenting large scattered aggregates of felspar in a black fine-grained crystalline matrix. One of them is well seen about half a mile, and the other about 1500 yards, S.S.W. of the hill top. Under the microscope (4193) the edges of the aggregates are seen to be frequently indented by small crystals of hornblende, and to blend with the general mass of the rock, which is a granulitic aggregate of hornblende and felspar. The felspar appears to be an oligoclase-andesine, and contains small inclusions of hornblende.

But even where the material of the dykes has become distinctly schistose, the forms of some of the original minerals may occasionally be detected. Thus, between Loch Garbhaig, north of Ben Slioch, Loch Maree, and the north and south burn, rather more than a mile west of that loch, various bands of hornblende-schist contain somewhat idiomorphic porphyritic forms composed of granules of felspar. One of these bands, about 1000 yards

* This dyke is mentioned again in this chapter.

W.N.W. of the outlet of the loch, is composed of different layers that vary slightly in character; some of them show the porphyritic forms, often about half an inch long, so crowded together as to equal in bulk the rest of the rock, while in other layers these inclusions are rare or absent. Again, about 1000 yards north-east by north of Furnes, a hornblende-schist appears, parts of which are full of porphyritic forms of felspar giving lath-shaped and squarish sections. Near the sides of the schist, and along certain bands in the interior of the dyke, these felspars have been sheared, and are represented by thin parallel streaks.

The basic dykes vary in breadth from a few inches to 100 yards or more. The same dyke may likewise differ considerably in width at various parts of its course. Thus, three-quarters of a mile north-west of the outlet of Loch Braigh Horrisdale a dyke has a breadth of about 110 yards, but a quarter of a mile further north-west it measures only 40 yards.

In two of the unfoliated dykes, one, already referred to, on the headland W.N.W. of Ardlair, and the other 200 yards south-east of the top of Sithean Mor, $2\frac{1}{4}$ miles south of Gairloch, two distinct types of material have been observed which may belong to successive intrusions. In each case the coarser rock appears to be the older, but it may perhaps not have thoroughly cooled when the other material was injected, for in the last-mentioned dyke coarse veins, like the segregation veins of an igneous magma, cross both varieties of rock.

The dyke just referred to shows no foliation in the centre where it is an ophitic-dolerite, yet contains several fine-grained bands, a yard or two broad, that display sharp junctions with the coarse rock. Some of these were traced 20 or 30 yards nearly parallel to the sides of the dyke mass in which they occur. The fine-grained type is composed of the same materials, but shows a micro-porphyritic structure.

In most of the foliated dykes the foliation is parallel to the sides of the dykes. The margins are more closely foliated than the interiors, and in the broad dykes are often finely schistose, while the central portion may remain, wholly or in part, in a massive condition. Not unfrequently closely foliated parts wind round large eye-shaped masses of less foliated, or even massive, rock. A dyke half a mile south-east of Sithean Mor ($2\frac{1}{4}$ miles south of Gairloch) exhibits a string of such masses, about a yard broad and from two to four yards long, connected together by narrow constrictions and having their long axes parallel to the trend of the dyke.

That the foliation in the dykes in the Loch Maree district is in most cases parallel to their margins, and most perfectly developed near the sides, is no doubt due to the fact that most of the movements which gave rise to the foliation have, in this district, proceeded along the lines of the dykes. These movements have often had less influence on the contiguous gneiss than on the dykes, many of which are well foliated, while the adjoining gneiss shows comparatively little alteration.

Few bands of hornblende-schist, which can be proved to represent dykes, show so close a foliation as that frequently observable in the thick hornblende-schists associated with the altered sediments in the Lewisian gneiss. There can be little doubt, however, that some of the very finely-foliated thin bands on An Ard (Gairloch), and between there and Loch Kerry, represent dykes, for they are flanked by gneiss on either side. The intensity of shearing which has produced the very close foliation has probably sufficed to destroy the evidence of the intrusive character of many of the bands.

Where the dykes are foliated throughout in directions transverse to their course, the foliation in them corresponds with a second foliation in the gneiss, or with an early banding which has been thinned and modified. In the latter case, the modified banding represents both the first and second foliation. In a section nearly a mile slightly north of west of Mullach nan Cadhaichean, the foliation in a dyke is transverse to the side, and the second foliation in tne gneiss is parallel to the axial planes of some small folds which are seen in the gneiss, but which do not seem to affect the margins of the dyke. As the foliation planes in the dyke are continuations of the second foliation planes in the gneiss, the foliation in the dyke must have been produced at the same time as these folds, though no indications of folding are to be observed on the sides of the dykes. The foliation which has been produced simultaneously in both gneiss and dykes is in some districts so strong that it obscures the early broad bands which existed in the gneiss before the dykes were intruded. These early bands have also been dragged so that their outcrops are almost parallel to the dykes.

Although the mechanical deformation which the dykes have thus undergone has to a large extent destroyed the evidence of their intrusive character, abundant satisfactory proofs of their original injection into the surrounding rocks have been obtained in many areas, particularly near Loch Braigh Horrisdail, and Meall an Tuim Bhuidhe. Near Lochan Druim na Fearna various bands of hornblende-schist can be traced for a mile or more keeping so nearly parallel to the limestone that their original dyke-like character might well be doubted, were it not for the phenomena seen a little further south-west, where, after passing many parallel bands of similar schist separated by thin strips of gneiss, we reach, near Mullach nan Cadhaichean, a series of hornblendic bands which are generally less sheared than those near the limestone, and display repeated evidence of intrusion.

On the north-east side of the thick hornblende-schist near Loch Bad an Sgalaig, Loch Airidh a' Phuill, and near Meall Airidh Mhic Criadh, between Loch Gairloch and Loch Maree, the parallelism of the foliation planes in the dykes and gneiss is marked. The rocks at the last locality lie in the steep south-west limb of an anticline of later date than the basic dykes, and during the folding they have been sheared and partly dragged into parallelism. The central parts of the same arch contain bands of hornblende-schist which are, as a rule, rather coarser in grain than those on the Meall, and often posses a linear instead of a plane-parallel foliation. Between the hornblende-schist bands in the centre of the fold and those on the Meall many others occur. Although at no place is there any sudden change in character, yet in the centre of the anticline, where it may be supposed that there has been less alteration by dragging and shearing than in the south-west limb, nearly every hornblende-schist shows clear indications of intrusion.

Some of the hornblende-schists in the gneiss area between Folais and Slioch (north-east of Loch Maree) show their original intrusive character. This is best seen about half a mile south-west and half a mile south of the outlet of Loch Garbhaig. The dykes are distinctly folded and lie near the axial plane of the great syncline of Folais and Beinn Airidh a' Char. The sides of some of them strike steadily north-east for several hundred yards and are inclined at gentle angles.

Over a large part of the ground west of Fionn Loch gently-inclined bands of hornblende-schist are certainly intrusive in the gneiss. On the north side of the anticline in that area the Meall na Meine basic band, which is 300 yards wide near the Ordnance station, chiefly consists, both here and to the west, of a massive, coarse diorite or epidiorite with little foliation except along its southern edge. The rock dips north with the gneiss, and is grey in colour with white felspar. Further east it is sheared almost throughout, becomes a much narrower band, and before reaching Fionn Loch disappears. The mass forming Meall Dhuireadh Airde appears to dip north-east and to underlie that of Meall na Meine, yet it may be the same rock repeated by an isoclinal fold. A marked line of shear intervenes between it and the similar mass that comes on a quarter of a mile south-east, which may be again the same band. This outcrop has an irregular outline, but in the main runs in a southerly direction, dipping at a comparatively low angle and spreading out on the dip slope. It distinctly crosses the strike of the gneiss foliation.

A broad band of the same kind of rock, with a southerly dip, runs east towards Fionn Loch, and this is probably connected with the mass north-east of Kernsary (two and a half miles south-east of Poolewe). At Loch nan Carn it has a breadth of at least 250 yards, and it dips S.S.W. at 30° or 40° nearly coincident with the adjacent gneiss, though it clearly crosses the foliation of that rock. South of Kernsary a coarse massive epidiorite, partly foliated, trends in a N.N.E. direction. Its west boundary is fairly regular, but from its east side project two spurs which may be due to folds. It is more than 200 yards wide at its south end, but narrows considerably in a northerly direction. Its relation to the ordinary dykes is doubtful.

After their intrusion many of the dykes underwent a process of shearing by which intense foliation was produced. In certain

cases folding took place later than the production of the first foliation. In some areas the dykes have been thrown into sharp folds with axial planes striking north-west, almost parallel to the original direction of intrusion, so that the dykes in the limbs of fold do not differ much in direction from those which have not been plicated. Near the centres of other more gentle folds, the divergence from the original directions is conspicuous, and, for distances of a quarter of a mile or more, dykes strike north-east and dip at low angles, so as to look like sheets rather than dykes.

If vertical dykes are affected by folds the axes of which are horizontal, it appears that the sides of the dykes will remain vertical, though different points in the margins must receive an upward or downward motion, and the horizontal distance between points which are not in the same vertical line must be decreased. Similar movements will affect the whole of the interior parts of the dykes, and hence a foliation may be produced throughout the rock. In other cases, as, for instance, near the top of Meall Airidh Mhic Criadh and nearly a third of a mile north-west of Loch Doire na Herrie, the sides of a dyke are clearly plicated, and the foliation in the dyke is parallel to the axial planes of flexure and the second foliation in the adjoining gneiss. In these cases the pitch or inclination of the axes of fold is steep.

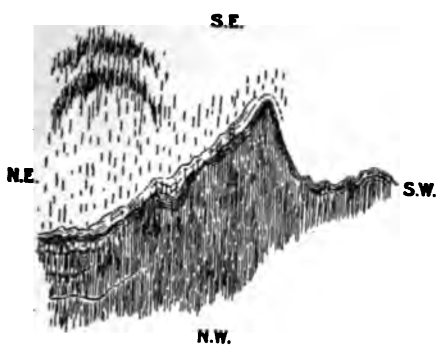


FIG. 9 ($\frac{1}{60}$).—Ground plan of foliated basic dyke and acid gneiss, about 200 yards south-east of south end of Loch nam Buainichean. The marginal portion of the dyke is foliated parallel to the side. This portion, the foliation in it, and some quartz veins are folded and occasionally crossed by a strain-slip foliation parallel to the axial planes of fold. The interior of the dyke is foliated parallel to the same axial planes. A thin strip of gneiss next the dyke is foliated parallel to the dyke side, and follows the same folds. The prominent foliation in the rest of the dyke is parallel to the axial planes of these folds. Near the south-east side of the exposure there are indications of an early banding in the gneiss.

In a nearly horizontal exposure, about 250 yards south-east of the outlet of Loch nam Buainichean (two and three-quarter miles E.S.E. of Gairloch), a dyke can be seen to have been first foliated parallel to the side, and for a short distance inwards from the margin, and then subsequently plicated and further foliated in a direction parallel to the axial planes of fold. The foliation planes parallel to the side are folded, and crossed by strain slips parallel to the axial planes of fold.

It is noteworthy that nearly all if not the whole of the foliated dykes which occur in the areas S.E. of Loch Tollie, between Folais and Slioch, near the Dubh Loch of Carnmore, near the Sron a' Choit (one mile west of Talladale), N.N.E. of Beinn Bhreac (six miles S.S.E. of Shieldaig on Loch Gairloch), and east of Loch a' Ghobhainn (two miles north-east of Beinn Bhreac) must have been foliated throughout before they were plicated, for their foliation planes share in the folding of the dyke outcrops.

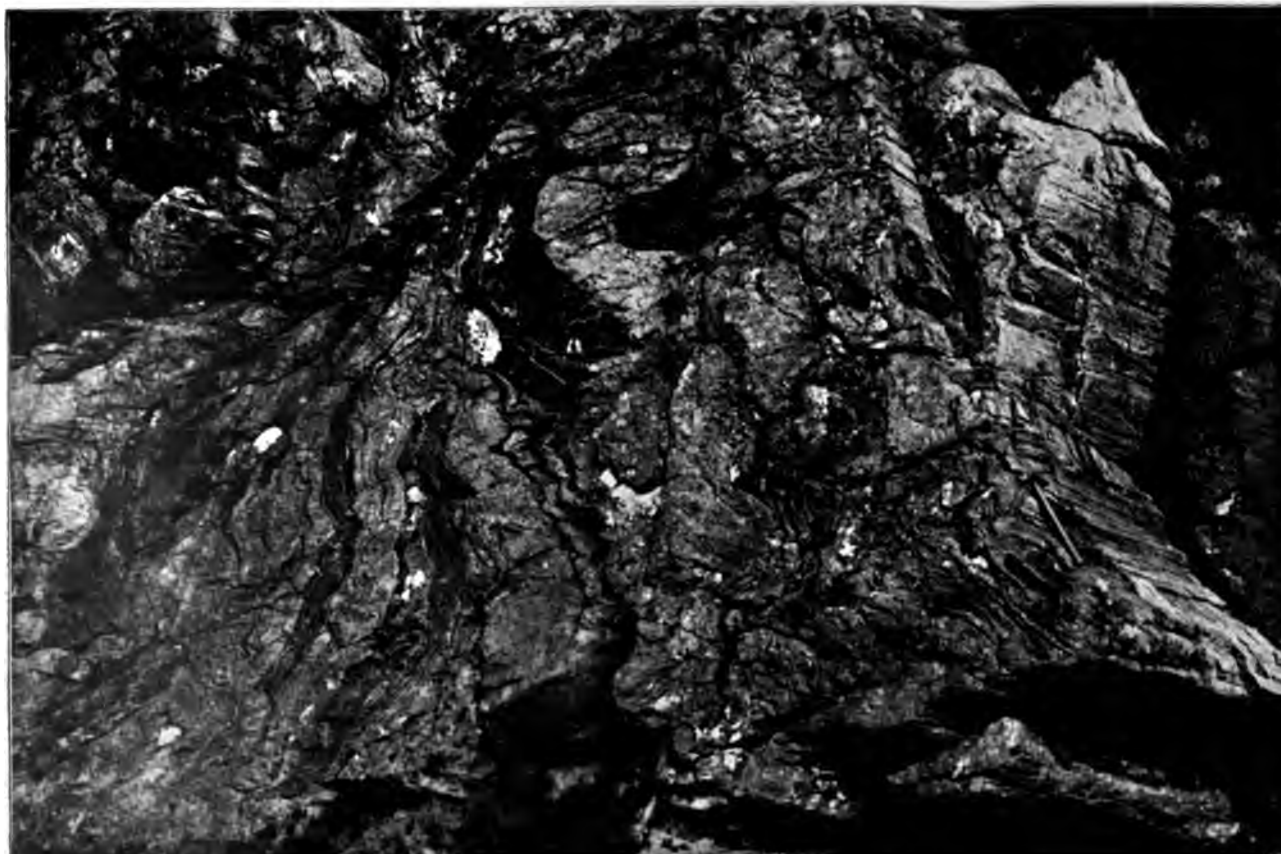
In several places it would seem that the more gentle folds which plicate the outcrops were preceded by others which folded them more sharply. Thus, on the east side of Loch Garbhaig, south-west of Talladale, the great fold which folds the outcrops has an axial plane that strikes slightly west of north, and its axis is almost vertical. In two or three places on the east limb the dyke rocks are arranged in such a way as to suggest that they have also been sharply folded along axial planes which now strike N.N.E.

In the more sheared areas it is occasionally difficult to decide whether the irregularity of form of some intrusions is due to folding or not. About a third of a mile north-east from the south end of Lochan Sgeireach, in an area in which the dykes are almost free from foliation, two dykes unite, and in the space between them a third appears which gradually dies out as it approaches the place of union of the other two. Similar arrangements are also seen about 700 yards east and half a mile north of Loch nam Buainichean, and in other places. In the dykes cited from Loch nam Buainichean the appearances are no doubt due to folding.

The hornblende-crystals always lie parallel to the foliation planes of the foliated dykes, and they have usually a general direction—the direction of stretching—on these planes. Some of these directions are shown by signs on the published one-inch map (91) which only indicate their horizontal projections. To find the actual trend in space note has to be taken also of the dip of the planes on which the indications are seen, which may be assumed to be the same as that shown by the nearest of the dip signs on the map.

In the south-west limb of the Loch Tollie anticline the variations in direction of the stretching lines are considerable. When the lines appear diagonal, their upper ends are sometimes on the south-west and sometimes on the north-east side, but in various places, for instance, about 700 yards E.S.E., and half a mile south-east, of the head of Loch Tollie, and rather more than half a mile north-east of Meall an Spardain, the lines are nearly horizontal and parallel to the strike. In the north-east limb of the anticline the lines generally appear diagonal, and with their upper ends on the north-west side. Near Meall Lochan a' Chleirich (one mile west of Slattadale, Loch Maree) the stretching lines are more nearly with the direction of the foliation dip than with the strike, and their upper ends are on the south-east side. They are in some places affected by minute folds, the axes of which cross them nearly at right angles.

In the foliated dykes three-quarters of a mile N.N.W., and a mile and a third north-west, of Carnmore Old House the



Convoluted Hornblende-Gneiss. **Striations on surface to right are parallel to the slope of the mullion surface in Plate XXV. Meall an Spardain, Poolewe, Ross-shire.**

stretching lines are diagonal to the direction of dip of the planes on which they occur, and their upper ends are on the south-east side, but the amount of variation from the direction of dip varies in different places. In the dykes two-thirds of a mile north-east of Strathanmore, and about 1000 yards south-east of the foot of the Dubh Loch of Carnmore, the stretching lines appear diagonal and their upper ends are on the north-west side.

In the most finely foliated dykes the hornblende crystals are thin and needle-like, but in others they present stout or stumpy forms. In specimen 4434, obtained 1100 yards north of Meall an Spardain (two and a half miles south of Poolewe), from a dyke which is now composed of a rodded or linearly foliated hornblende-schist, the hornblende is compact and indistinguishable under the microscope from that which occurs in the typical granular hornblende-gneisses.

Flakes of biotite are common on the foliation planes of the best-foliated dykes near Meall Airidh Mhic Criadh, south-west of Loch Tollie, Poolewe, in the area between Folais and Slioch, and near Strathanmore (Fionn Loch). Near Carnmore several thin bands of hornblende-schist are much more micaceous than others near them. One of these, about three feet thick, makes a conspicuous recess in the crags rather more than a quarter of a mile north-east of the Old House. Other thin bands of a similar kind occur on the north-east side of the N.N.E. fault rather more than two-thirds of a mile north-west of the Old House, about 1500 yards slightly west of south of the outlet of Lochan na Bearta (three miles east of Fionn Loch), and 300 yards W.N.W. of Meall Lochan a' Chleirich (one mile west of Slattadale, Loch Maree).

Some of the foliated dykes which contain conspicuous flakes of biotite, or chlorite, may have originally differed slightly in composition from the others. But the unusual abundance of these flakes may possibly be due to the greater intensity of the shearing which the dykes have undergone. Satisfactory evidence has been obtained in several places that after dykes had been converted, wholly or partially, into hornblende-schist, renewed movements took place which transformed the dyke-rock, whether it was previously foliated or not, into a shivery micaceous or chloritic schist. An example of this change has been found near the top of Sithean Mor, south of the village of Gairloch, where a massive epidiorite has become a shivery micaceous hornblende-schist with foliation-planes parallel to a line of thrust.

Again, about half a mile north of Meall an Spardain, a coarse almost vertical N.N.E. pegmatite, a foot or two thick, which crosses a broad hornblende-schist, is sheared parallel to its own sides, and the hornblende-schist near it is also in some places converted, for a thickness of a few inches, into a fissile chloritic schist, the foliation planes of which are often crumpled, though their general direction is parallel to that of the pegmatite.

About 700 yards E.S.E. of the head of the Dubh Loch of Carnmore a quartz vein, from 12 to 20 feet thick, appears within a thick hornblende-schist which represents a foliated and folded dyke. The schist dips north-east at gentle angles. The vein lies nearer the base of the schist than the top, and is almost parallel to the base. Above it comes hornblende-schist of the common type, but the schist below is biotite-actinolite-schist, the foliation planes of which dip steeply south. The quartz-vein probably marks a line of movement, the foliation-planes of the schists at either side of it striking against one another. The vein contains scattered hornblende crystals, streaks of biotite-actinolite-schist, and irregular patches, as much as a foot thick, of a coarsely crystallised carbonate which contains some diopside.

Some of the foliated dykes contain grains of magnetite of the size of small peas, as may be seen in the crag about a mile slightly north of west of Loch Garbhaig, north of Slioch. These grains are generally elongated in one direction, and are often bounded in part by grains of quartz. In a hornblende-schist, on the west side of the burn rather more than two-thirds of a mile north-east of Furnes, magnetite specks are so abundant that hand-specimens affect the compass.

Garnets, sometimes as large as peas, have been abundantly developed in some of the foliated dykes. They never show good idiomorphic outlines, and most of them are edged with a thin rim of small granules of felspar. They are also often accompanied by small white spots, which seem entirely composed of such granules. Both the garnets and the white spots are particularly common in the dykes which lie between lines connecting Loch Shieldaig, south of Gairloch, and Busbheinn, on the north-east side, and Port Henderson and Beinn Bhreac, on the south-west.

The garnetiferous hornblende-schists are often divided into parallel layers, some of which are much richer in garnets and white spots than others. These sometimes agree in direction with the side of the dyke and the planes of foliation, and sometimes are oblique to the margins. About 1500 yards S.S.W. of the inlet into Loch Gaineamhach (three and a half miles S.S.E. of Shieldaig on Loch Gairloch) a folded dyke contains much crumpled bands in which white-edged garnets are specially abundant. This crumpling no doubt took place during the plication of the dyke. The bands are crossed by a foliation that strikes north-west parallel to the axial planes of fold. About 700 yards S.S.W. of Mullach nan Cadhaichean (two and a quarter miles S.S.E. of Shieldaig on Loch Gairloch) the white spots and garnets have in certain places been deformed and affected by a foliation, but in most of the hornblende-schists such is not the case. It is probable, therefore, that the shearing and foliation which sometimes affect the garnets are later than the foliation found in most of the dykes. A broad dyke about 700 yards E.S.E. of the outlet of Loch Braigh Horrisdale, which is closely foliated at the sides, but almost free from foliation in the central half, displays abundant white-edged garnets and white spots in the foliated parts, but none could be found in the middle portion. The formation of the garnets probably accompanied the development of the foliation. No garnets with white rims have been noticed in any dyke which is quite free from foliation. There are garnets in an unfoliated dyke in the headland a mile W.N.W. of Ardlair (north-west end of Loch Maree), but these have no white rim.

The best examples of "rodded" or linearly foliated dykes occur between Tollie Bay and Ob a' Choir-uidhe (a bay at the west end of Loch Maree), and on the north-west side of Doire: especially clear are those which successively appear a third of a mile east, rather more than a quarter of a mile south-east, and three-quarters of a mile slightly east of south from the summit of Creag Mhor Thollie. In the exposures of these dykes, which happen to cross the direction of rodding almost at right angles, no plane-foliation is observable, the ends of rod-like parts being only exposed. It is not known that the dykes in the area between Tollie Bay and Ob a' Choir-uidhe have been folded, but those near Doire have certainly been.

Some of the sheared dykes N.N.W. from the outlet of Loch Braigh Horrisdale include veins with greenish-grey crystals of one of the minerals of the epidote-zoisite group. At a place half a mile N.N.W. of the loch the veins are half an inch thick, and cross the dyke almost at right angles.

ULTRA-BASIC DYKE.

Only one ultra-basic dyke, composed of hornblendite, has been noticed in this district. It is seen rather more than a mile and a quarter W.N.W. of Ardlair. In the published one-inch map (91) it has been coloured like the basic dykes. It runs north-west parallel to broad dykes of epidiorite, is a few yards thick, and has only been traced about 100 yards. It is not foliated, and its intrusive character is quite clear.

SYENITE DYKE.

About a third of a mile south-east of Carnmore Old House a thin dyke may be seen, from five to eight feet thick, extremely coarse in texture, and chiefly composed of hornblende and microcline. Some parts of it are massive, others, particularly near the south-east side, are foliated parallel to the margin. The dyke can be traced 160 yards in a N.N.E. direction with occasional twists. It shows a rather low inclination towards S.E. The hornblende crystals in this dyke are sometimes three-quarters of an inch long, appear dark-green macroscopically, and contain inclusions consisting of granular aggregates of reddish microcline. The felspar is generally subordinate to the hornblende in amount. The dyke contains some thin veins of still coarser grain than the general mass.

PEGMATITES.

Pegmatites of later age than the basic dykes are abundant in two areas in the Loch Maree district, one near Loch Tollie and the other near Carnmore. The former stretches from Naast, on the south-west shore of Loch Ewe, to Loch Doire na Herrie, four miles S.S.E. of Poolewe, and the latter from the sides of the Dubh Loch for about three-quarters of a mile. They appear in the gneiss of the Fundamental Complex, in the dykes and in the altered sediments. As they are harder than most of the rocks in which they occur, they form prominent exposures or crags in the partly drift-covered areas. Most of them are irregular in direction and small projections and branches appear at their margins. In both the Loch Tollie and Carnmore areas the most general trend is perhaps towards north-west, irrespective of the foliation of the rocks which they traverse. In the crags 1500 yards south of Carnmore, where the strike of the gneiss varies between east and north-east, the transgression of the pegmatites across the foliation is remarkably clear.

The common constituents of these pegmatites are plagioclase, orthoclase, and microcline felspar, biotite, muscovite, and quartz, but the proportions of these minerals vary considerably in different exposures. For example, biotite is sometimes largely developed, as in a pegmatite a third of a mile south-west of the summit of Creag Mhor Thollie, where the flakes are several inches long, and in another instance, three-quarters of a mile S.S.W. of Tollie Farm, similar scales exceed four inches. In other places this mineral is scarce or absent altogether. The white mica (muscovite) sometimes reaches larger dimensions. In the crags north-east of Carnmore it often occurs in idiomorphic crystals from one to three inches long and from a quarter to one inch thick in a direction across the basal cleavage. In the tumbled blocks from a white pegmatite a mile and 200 yards west of south of Carnmore, some of the crystals are ten inches long and three or four broad. The larger crystals are often cleaved transversely to the basal plane. The folia are generally somewhat bent and occasionally sharply twisted.

Most of the pegmatites in the Carnmore and Coppachy areas (north-east of Loch Maree) contain more white felspar than red. In the tract north-east of Carnmore the white felspar is sometimes enclosed within the red. Intergrowths of two felspars are common in these rocks as, for example, north-east and a mile and 200 yards west of south of Carnmore. A specimen tumbled from a vein at the last-mentioned locality consists of large crystals of orthoclase, intergrown with plagioclase. Another, from a pegmatite more than a third of a mile north-east of Carnmore Old House, consists of a large individual of microcline containing muscovite and quartz. Graphic intergrowths of quartz and felspar appear in pegmatites in the crags 1500 yards south and north and north-east of Carnmore and on the north-east side of Lochan Fada. In a vein, about three inches wide, in the crag about 1500 yards south of Carnmore the outer parts are composed solely of quartz, while the inner consist of quartz and felspar.

Both in the Loch Tollie and Carnmore areas the rocks in which the pegmatites are found are near the centres of anticlines, and may have been covered by considerable thicknesses of material at the time of the introduction of these acid veins. Many pegmatites cross dykes of hornblende-schist, though themselves free from foliation, or only partly sheared, along lines formed since the foliation of these intrusions.

No thick massive pegmatite which shows clear evidence of folding has been detected, but the movements which plicated the various mylonised rocks between Folais and Slioch probably took place after the introduction of the pegmatites, as mylonised pegmatites adjoin the folded bands. Zones of mylonised pegmatite are common, but, excepting in the tract just mentioned, are rarely more than a foot or two thick. The pegmatites near Coppachy have more often been mylonised than the adjacent rocks, and the mylonised examples contain numerous eye-shaped pieces of pink or white felspar, some of them as large as a hen's egg, in which one cleavage plane crosses the entire breadth. Felspar crystals of such a size are rare in any of the Archæan rocks, except in the pegmatites. Most of the pieces have rounded outlines and look like corroded phenocrysts embedded in a fine-grained streaky pale-grey or greenish-grey felsitic matrix. The subparallel streaks of which the matrix is composed vary in translucency, and are often so thin that thirty can be counted in a thickness of half an inch. They wind round the sides of the felspar "augen," and are sometimes also sharply folded. On the surfaces of the streaks small flakes of a nearly colourless mica may usually be observed. Many of those flakes are from 1-10 to 1-20 inch in length, and considerably twisted. They occur sporadically, and perhaps they have been derived from larger flakes which existed in the pegmatites before they were mylonised. In the thin slice of a specimen (4775), from a mylonised pegmatite half a mile north-east of Coppachy, the microscope discloses many minute scales of white mica which have probably been formed during the shearing. In the same slice some of the felspar "augen" show twin lamellæ which have been bent and twisted.

The greenish fine-grained rock, about 50 yards north-east of the mica-schist zone on the south-east side of Smiorasair (near the head of Loch Maree), probably a mylonised pegmatite, is hard, very fresh, weathering only in a narrow dirty white film, and sharply jointed. Its fracture is conchoidal. Microscopic examination shows (4277) the matrix to be crypto-crystalline and the grains in it to be composed of felspar and epidote. The felspars sometimes show plagioclase striation and give definite extinction. An analysis of the rock by Mr. Barrow gave the following result:—

Silica - -	72·9
Alumina - -	13·85
Ferric oxide - -	1·85
Lime - -	1·17
Magnesia - -	·72
Potash - -	5·21
Soda - - -	2·49
Loss on ignition -	1·5
	99·69

The broad pegmatite 200 yards south-west of Meall an Doirein (three and a quarter miles south of Poolewe) is sheared along a zone, several feet wide, which is nearly vertical and strikes parallel to the adjoining gneiss. The unsheared parts of the pegmatite consist of large crystals of red felspar and quartz, with little or no mica. In the sheared zone most of the felspar is granulitised, almost white in colour, and arranged in thin streaks parallel to the sides of the zone, but there are also eye-shaped pieces of felspar, an inch or two wide, which still retain the original red colour and the old cleavage planes. The quartz has also become finely granulitic, and has been pulled into streaks parallel with those of the felspar.

Subsequently to the first shearing of the pegmatites movements of later but still pre-Torridon age have in some places produced compact flinty rocks, such as appear about 350 yards east of Meall an Doirein.

ROCKS PRESUMABLY OF SEDIMENTARY ORIGIN ASSOCIATED WITH THE LEWISIAN GNEISS.

General Relations and Distribution.—It was the general belief of the old observers that the Lewisian Gneiss, like the primitive gneiss everywhere, is as a whole of sedimentary origin. In later years, when the igneous character of many of these rocks had been recognised, Dr. Hicks* maintained that some of the schists near Gairloch and Loch Maree were metamorphosed sediments. In the detailed mapping of the region the Geological Survey has endeavoured to separate certain bands which would by general consent be classed as probably altered sediments, but it is possible that future investigation may indicate that other zones not here included may also be of sedimentary origin. A satisfactory separation of those schists and gneisses which have the most sedimentary aspect from the other foliated rocks which seem to be of igneous origin—the ortho-gneisses—seems at present impossible. Many of the

* "On the Pre-Cambrian Rocks of West and Central Ross-shire." *Geol. Mag.*, 1880, p. 104.

supposed sediments have ill-defined margins, and both they and the adjoining gneisses have been much sheared and crushed. It is noteworthy that one of the commonest of what are taken to be sediments is a flaggy brown mica-schist, resembling granulitic bands which in Sutherland have in many places been formed along pre-Torridon shear-lines from more massive gneisses.

There is no proof of the intrusion of the gneissose rocks of the Fundamental Complex into the supposed sediments, nor yet of the unconformability of the latter on the former. In certain places bands of marble and of kyanite-gneiss lie within gneisses of common type in the complex, and pass gradually into them. It is suggested that these gneisses may be in part of sedimentary origin, and may belong to a formation of the same age as the limestone. The bands of kyanite-gneiss and one of the marbles lie at some distance from the most-sheared areas, and in districts where the intrusive characters of many of the basic dykes remain distinct.

The evidences of shearing and crushing, in and near to most of the sedimentary zones, are generally greater than in the adjacent rocks. Great intrusions of igneous material, most of them now in the form of hornblende-schist, appear also to have been injected along the margins. Most of the rocks which have been mapped as altered sediments present smooth features in the landscape and show comparatively few rock-exposures. They contrast strongly with the bare hummocky areas of gneiss at their sides, and with the crags of hornblende-schist associated with them.*

In Gairloch the chief belt of these altered sediments extends for seven or eight miles in a south-east and north-west direction, from a mile and a quarter south-east of Loch Bad an Sgalaig to the coast east of An Dun and the road between Strath and Poolewe, and there are traces of it about two miles further north-west. Its width is about a mile and a quarter, half of which is occupied by bands of hornblende-schist or hornblende chlorite-schist. Consisting for the most part of a fine-grained brown mica-schist, it contains also various bands of limestone, graphite-schist, and quartz-schist or quartz-magnetite-schist.

There are other detached smaller bands, one of which strikes south-east from Loch Kerry (at head of Loch Gairloch), reaches the river Kerry about half a mile S.S.E. of Kerrysdale, and can be traced thence nearly to the foot of the Dubh Loch. The distance between it and the Bad an Sgalaig belt diminishes in a south-east direction, and on the south-east side of the fault near the Dubh Loch it is possible that the two are united. (See Sheet 91.) Another band composed of brown mica-schist occurs about 170 yards south of the Free Church Manse at Gairloch. On the south-east side of Shieldaig a band of micaceous or chloritic schist, 120 yards broad at its greatest width, often calcareous

* Near Scourie and Loch Inver, however, equally smooth features characterise some of the pre-Torridonian sheared rocks which have been formed from massive gneiss.

and with outcrops of marble, emerges from beneath the Torridon rocks. The marble bands north and south-east of Lochan Druim na Fearna are probably continuations of those near Shieldaig. Near these bands thin outcrops of granular quartz-rock can be seen. Again, bands of marble make their appearance near the north-west side of Am Feur Loch, nearly a mile and a half E.S.E. of the outlet of Loch Bad an Sgalaig, on either side of the bay near Gairloch Bridge, 160 yards above the foot of the Kerry, and at a few others places.

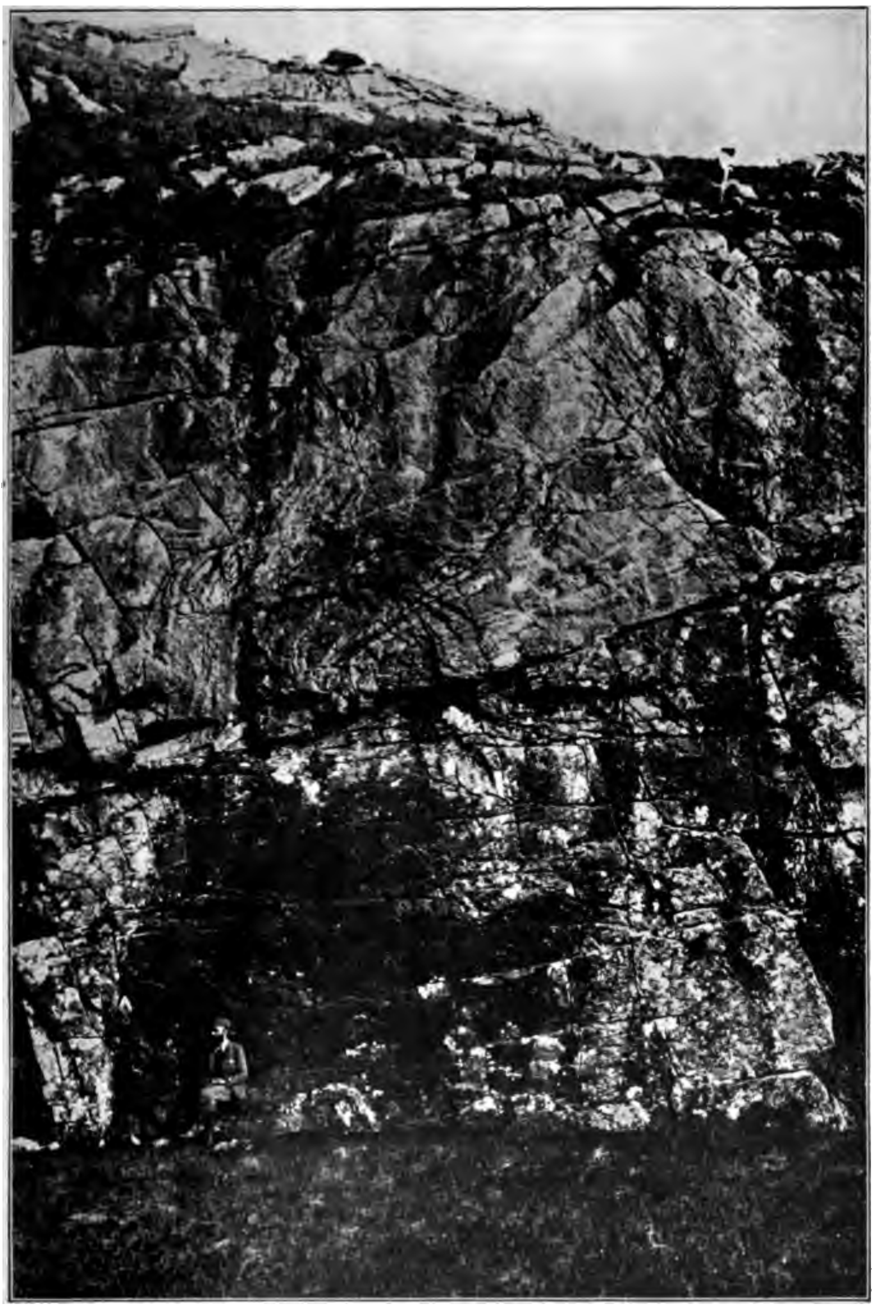
Along the north-east side of the Loch Bad an Sgalaig belt a series of nearly vertical pre-Torridonian flinty crush-rocks is exposed, separated in places by thin strips of gneiss from the altered sediments, or the adjacent broad band of hornblende-schist. Possibly other thrusts may have preceded the flinty crushes, and may exist where the latter are not seen. The thin bands of hornblende-schist in the gneiss on the north-east side of the broad band seem to have been folded along axial planes that make a slight angle with the outcrop of the thick hornblende-schist. It seems as if the latter were bounded on its north-east side by a great line of discordance.

Some difficulties present themselves if we suppose the altered sediments of the Bad an Sgalaig belt to lie in a complex syncline with gneiss on either side. No thick hornblende-schist appears at the south-west margin like that at the north-east, while all the bands of graphite-schist lie nearer to the south-western than to the north-eastern boundary. Near Bad an Sgalaig four outcrops of hornblende-schist appear in the south-western half of the band, but only one in the north-eastern (Sheet 91). These difficulties can, however, perhaps be explained by supposing, (1) that the hornblende-schist does not keep strictly to the bedding planes, (2) that some beds have been cut out in certain places by crush lines running parallel with the strike, (3) that thrusts have affected the great north-east limb of the supposed syncline, and (4) that the number and depth of the minor folds in the syncline vary in different parts.

A gneiss with felspar augen—a common type in the early complex—prevails on the south-western side of the Bad an Sgalaig belt of sediments. In several places near the same margin a fine flaggy augen-schist, which lies close to, and sometimes is mixed with, the mica-schists, might conceivably represent sheared pebbly sediments, but is more probably a sheared form of massive augen-gneiss like that a little further south-west.

That the Loch Kerry band of sediments is perhaps bounded by thrust lines on both sides is suggested by the following considerations. Some hornblende-schists in the gneiss on the north-eastern margin do not seem to be affected by a large fold which plicates part of the sediments. The evidence for a line of discordance on the south-west side is stronger. On the hill a mile S.S.E. of Kerrysdale a thick band of hornblende-schist, with nearly vertical pitch, is folded along an axial plane striking

PLATE XXVII.



Junction of Hornblende-Schist with banded Hornblende-Gneiss.
Meall an Spardain, Poolewe, Ross-shire.

north-west and south-east, the nose of the fold pointing north-west. The rocks on the north-east side of the hornblende-schist, and some thin partings in this schist, are the presumably sedimentary mica-schists and graphite-schist, which ought to appear on the south-west limb of the fold. But those in the latter position form a valley, are extremely sheared, and differ from the mica-schists on the other side in containing many small augen of felspar, and alternations of siliceous and dark hornblendic bands which perhaps represent sheared forms of gneiss.

In Plate XXX., Section A, an attempt is made to represent what appears to be the probable relations of the chief groups of rock in the Gairloch area as they occur along a line of traverse from near Shieldaig in a north-easterly direction to near the foot of Loch Maree.

The altered sediments on the north-east side of Loch Maree closely resemble those of Gairloch, with which they were probably once continuous. Like them, they are associated with broad outcrops of hornblende-schist, and consist for the most part of mica-schist, graphite-schist, and limestone, with bands which may represent altered quartzite and chert. The broadest development of these rocks stretches from Letterewe to Fasagh, and may be called the Furnes belt. Its length from north-west to south-east is about five miles, and its greatest breadth, including various outcrops of hornblende-schist, nearly three-quarters of a mile. Another, which may be called the Gleann Tulacha belt, can be traced from Lochan Fada along Gleann Tulacha to near Strathanmore, and thence round the north and west sides of Beinn Airidh a' Char till it approaches the side of Loch Maree, rather more than half a mile north-west of Ardlair. In some parts of Gleann Tulacha it may perhaps be a quarter of a mile wide, but to a large extent it is covered with drift.

Between the Furnes and Gleann Tulacha belts several minor bands can be followed north-west from the west part of Loch Garbhaig. One is visible on the south-east side of Beinn Airidh a' Char, and a second in a north and south burn from two-thirds of a mile north to 150 yards west of Folais. Both of these bands are affected by a common system of folds along axial planes striking north-west and south-east. For convenience of description these may be referred to as the Beinn Airidh a' Char and Folais bands. The latter contains the Letterewe limestone, formerly quarried near Folais, and traceable for several miles. A large fault runs from the foot of Loch Garbhaig to the side of Loch Maree a mile north-east of Regoilachy, on either side of which the arrangement of the rocks is different. On the north-west side the Folais and Furnes bands are separated by a broad outcrop of hornblende-schist, and no similar outcrop appears on the north-east side of the Letterewe limestone. On the south-east side of the fault, broad bands of hornblende-schist appear on both sides of the Folais band, and a zone of mica-schist which occurs near the limestone can be traced south-east until it coalesces with the Furnes mica-schist.

Another thin band crops out in the burn a little east of Meall Each, south-east of Slioch, which probably represents one of the belts near Loch Garbhaig, but it is separated from them by a cover of Torridon Sandstone.

A key to part of the structure of the south-western portion of the Furnes band is given at Regoilachy burn. All the way between Fasagh and that stream, in spite of frequent contortions, the hornblende-schists and the altered sediments seem in most places to be vertical. But, at the great crag overlooking the south side of the burn, the hornblende-schist is seen to lie in a sharp synclinal fold, and the mica-schists pass, with many contortions, underneath it. The apparent verticality in this district is produced by intense and rapid puckering within the large folds, so that across the crest of an anticline, or the centre of a syncline, the prominent inclination appears vertical on both sides. The graphitic and other schists north-west of Smiorasair probably on the whole dip nearly with the slope of the hill, so that a small change of dip, or of the declivity of the hill, suffices to alter the form of their outcrop.

The tectonic relations of the altered sediments to the north-east of Loch Maree are far from clear. The Gleann Tulacha, the Beinn Airidh a' Char, and the Folais bands, as well as the hornblende-schists which separate them, are certainly all folded into a complex syncline, the north-east limbs of which generally dip south-west, while the south-west limbs are themselves plicated, sometimes dipping north-east and at other times south-west. The hornblende-schist between the Furnes and the Folais bands is separated from the hornblende-schist which overlies the Gleann Tulacha belt by the Beinn Airidh a' Char sediments. Hence these bands of hornblende-schist cannot be the same, nor can the Furnes band be the same as that of Gleann Tulacha, unless the rocks were already folded before the development of the compound syncline, which is not an improbable supposition.

An attempt is made in Plate XXX., Section B, to show what are supposed to be the general tectonic relations of the rocks between Loch Maree and Beinn a' Chasgein Mor. The section is drawn several miles south-east of the north-western apex of the compound syncline, and does not show the evidence that favours the supposition of the existence of an earlier fold.

The thick hornblende-schists north-east of Loch Maree seem to have been foliated before the mylonising movements, for many pieces enclosed within the mylonites are indistinguishable from these schists. There may have been two periods of flexure later than the foliation of the hornblende-schists, and separated from one another by an interval during which certain rocks were mylonised. It also seems probable that the movements which plicated the mylonites in the Folais area were later than the broad flexure that affected the basic dykes near Carnmore, for the pegmatites and mylonites near the latter place seem to have been unaffected by folding.

Near the foot of the burn half a mile east of Isle Maree, and again on the hillside a mile and 350 yards S.S.E. of the top of Beinn Airidh a' Char, the hornblende-schist which there lies below the mica-schist approaches close to the hornblende-schist that lies above and on the east side of that zone. The two bands may conceivably belong to one sheet which has been plicated at different times, first so as to include the mica-schist between the two limbs of an acute fold, and thereafter to plicate the limbs of this early flexure and the mica-schist between them. On this supposition, the places where the upper and lower bands of hornblende-schist approach each other are near the axis of the early fold. In some parts of the hornblende-schist, particularly in the area between a mile and a mile and a third N.N.W. of Folais, the foliation-planes are twisted by flexures with axial planes striking north and south, both limbs hading east. Such plications are of the type which would account for the two bands of hornblende-schist being portions of one folded sheet.

It is not improbable that the Gleann Tulacha belt of sediments may be separated from the gneiss beyond by a line of thrust, for the north-east side of the Beinn Lair hornblende-schist and the Gleann Tulacha sediments, appear to cross the direction of some basic dykes in the gneiss further north-east. Some thin mylonised bands run with the Gleann Tulacha sediments, but they have not been seen north-west of Meall Mheinnidh, and perhaps some earlier line of thrust keeps along the junction of the sediments and the gneiss.

In the section rather less than a mile above the head of Lochan Fada a pale-grey rock, a few feet thick, comes between the Gleann Tulacha sediments and the gneiss on the north-east side. It differs from the gneiss in colour and in containing few or no parallel quartz-streaks, but conspicuous long prisms of hornblende. The quartz and felspar grains show cataclastic characters, but many of the hornblende prisms have idiomorphic terminations, are unstrained, and contain grains of the quartz and felspar. In the field it seemed as if this pale rock might possibly belong to the altered sediments, the hornblende having been developed by metamorphic action. The constituents are, however, the same as those in the red gneiss, with the exception of hornblende and possibly of orthite. Perhaps the pale rock should be regarded as a sheared form of the adjoining gneiss, though the foliation-dips in the coarse gneiss on the north-east side of the glen are much the same as those in the sediments. The boundary between the pale rock and the red gneiss is not sharp, but a specimen (4407) of the latter, taken at a distance of two or three feet from the pale rock, is granular rather than granulitic in structure.

A quarter of a mile south of Furnes, and between Regoilachy and Fasagh, the mica-schists are separated from the loch-side by gneiss with many bands of hornblende-schist, most of which certainly represent basic dykes. The line between the gneiss and the mica-schists is a pre-Torridonian dislocation. Between

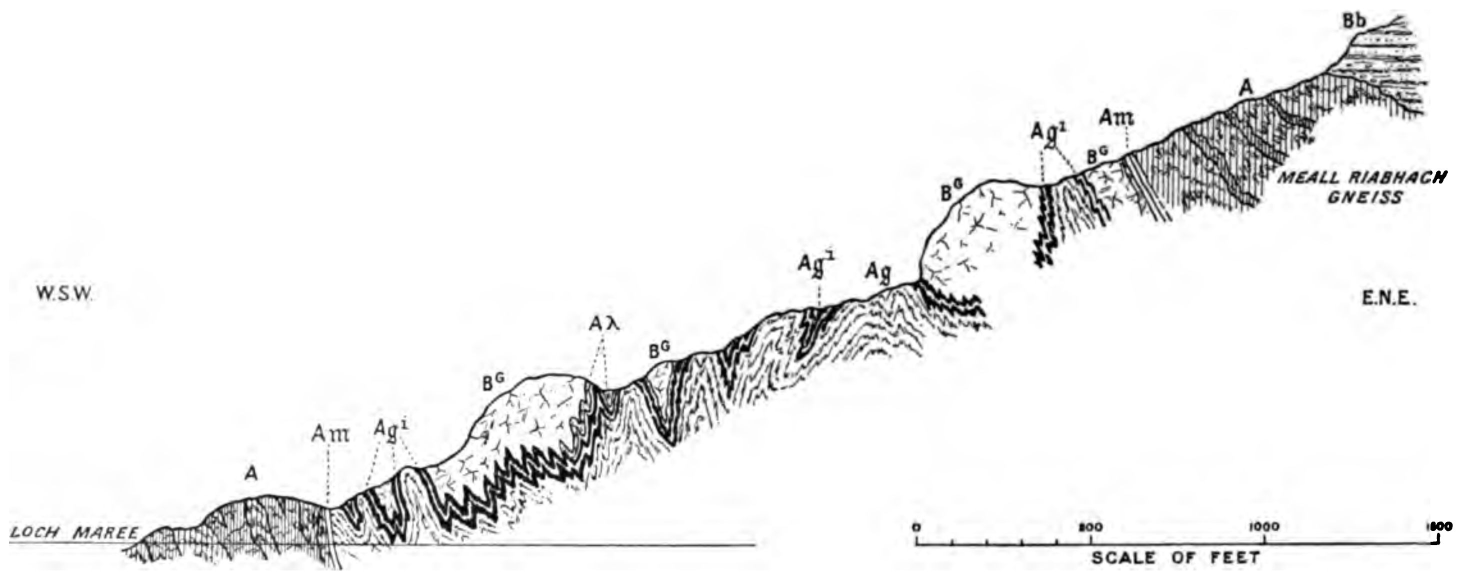


FIG. 10.—Generalised section proceeding from the coast 600 yards south of Regoilachy, Loch Maree, in an E.N.E. direction to the slopes of Slioch.

A. Gneiss of the Fundamental Complex with dykes.
Ag. Mica Schist.
Ag¹. Graphite Schist.
Aλ. Limestone.

BG. Hornblende Schist.
Am. Pre-Torridon Mylonised Rocks.
Bb. Torridon Sandstone.

Regoilachy and Fasagh the gneiss and the dykes become more and more crushed as they are traced away from the loch in a north-east direction towards the mica-schists. The gneiss is first crossed by many strings of a compact purplish-brown flinty, or felsitic-looking, material. Then the external aspect becomes affected, the rock weathers white, and the flinty material becomes general. The dykes are similarly affected but to a less extent. Both in the gneiss and dykes the flinty rock can often be seen to follow the planes of dislocation. The fault which bounds the gneiss on the north-east side has probably an upthrow to the south-west, but whether the crush phenomena observed in the gneiss are due to this line of movement is doubtful. Perhaps it is a later dislocation along an old line of weakness. The section in Fig. 10, which has been drawn from information supplied by Mr. Greenly, shows the general structure from Loch Maree, 600 yards south-east of Regoilachy, to the south-west slope of Slioch. About 600 yards south-east of Smiorasair burn, at a place where a marked feature appears at the north-east margin of the lochside gneiss, the gneiss seems to pass into the flaggy brown mica-schist, and the latter might be held to have been formed from the former by mechanical metamorphism. But perhaps a portion of the schist has been caught on the upthrow side of part of the fault, and has been so crushed with the gneiss that the rocks cannot now be distinguished.

In the centre of the syncline embracing the Folais and other bands of sediment massive pinkish gneisses are intersected with many bands of hornblende-schist, some of which are certainly altered basic dykes. These may be called the Leth Chreag* gneiss. In their present position these gneisses usually overlie the Folais and other sediments over an area four miles long by three-quarters of a mile broad, but this is not always so, there being some places where the south-west limb of the syncline is vertical or dips south-west. It is not certain that this superposition was originally brought about by thrusting, for the present synclinal arrangement of the rock-masses is later than most of the mylonising, and it cannot be determined how the mylonites were inclined before the syncline was formed. Possibly they were nearly vertical. Nor can the amount of movement be estimated which has taken place along the mylonites that now underlie the Leth Chreag gneiss, seeing that before the movement the sediments and associated rocks may have been folded, so as to be flanked by the more massive gneissose rocks on either side.

The various members of the series of presumably altered sedimentary deposits and their associated rocks in the district of Loch Maree and Gairloch will now be described in the following order:—(1) Mica-schists; (2) Mica-actinolite-schists; (3) Graphite-schists; (4) Granular-quartz-rock; (5) Quartz-

* Leth Chreag is the name of a crag in which this gneiss and the horn blende schists are unusually well seen. It is not named in the one-inch map, but it lies about a mile W.N.W. of Loch Garbhaig and trends N.N.E.

magnetite-schists and Quartz-schists; (6) Quartz-hornblende-schists; (7) Limestones; (8) Calcareous Biotite-hornblende-schists; (9) Kyanite-gneiss; (10) Cummingtonite-garnet-schist; (11) Chlorite-schists; (12) Hornblende-schist and Hornblende-chlorite-schist; (13) Hornblende-schists with brown mica and pyrites; (14) Actinolite-schists without either quartz or felspar.

(1) *Mica-schists.*—A flaggy brown mica-schist is the most common type of the altered sediments, and is especially abundant in the Gairloch area. It has a close resemblance to a mica-schist near Findlater Castle, Banffshire, but, unlike it, does not in most parts contain actinolite. Owing to the presence of small specks and streaks of pyrites, it often weathers with a rusty surface. Its foliation planes are coated with small flakes of white, black, or bronze-brown mica, and it splits readily along the foliation, but the cross fracture is rather conchoidal. Good exposures of this schist may be seen by the road half a mile south of Meall Aundrary, on the south side of A' Chosag, and in the burn at the side of the wood west of An Groban, all situated to the east and south-east of Gairloch. These several outcrops lie in the same broad band which stretches from the Torridonian rocks on the north slopes of Bus-bheinn to the road between Strath and Poolewe. The width of this band is in many places nearly half a mile, but it diminishes on the north-west side of Loch Mhuilinn. On the south-west side of this broad band, and separated from it by hornblende-schist, various thinner bands have been observed.

On the north-east side of Loch Maree the mica-schists are much mixed with thin graphitic-schists. They also contain in many places large crystals of dark actinolite—a mineral which appears to come in sporadically. Those schists in which it is specially abundant are described in the sequel (Sec. 2, p. 224). Near the path between Letterewe and Fasagh a band of mica-schist extends about five miles in a north-west direction. North and north-west of this band various much-folded zones of mica-schist appear at the sides of or between outcrops of fine hornblende-schist, like that forming the bulk of Beinn Lair. One of these bands strikes north from about half a mile east of Isle Maree for about a mile and a half. Another occurs in Gleann Tulacha, below the Beinn Lair hornblende-schist. Other outcrops are found near the top of Beinn Airidh a' Char, between the heads of the two burns which run westward from this hill, and north of the limestone quarry on Am Marcach.

In Gleann Tulacha a dark-brown foliated rock is seen on either side of the limestone in a little burn two-thirds of a mile above the head of Lochan Fada, on the north-east side of the limestone in a section rather less than a mile above the head, and in other places. It is more massive and felspathic than the common type of mica-schist in Gairloch, and contains epidote crystals, some of which are half an inch long. Biotite generally considerably preponderates over white mica, but large plates of the latter mineral sometimes lie across the foliation-planes. Calcite occurs in some bands as an essential ingredient in close association with the granulitic felspar and quartz. Small grains of black iron-ore and scattered prisms of tourmaline can often be seen with the unaided eye. In specimen 4413, from 1540 yards W.N.W. of Lochan Fada, part of the felspar is microcline. Scattered crystals of hornblende may occasionally be observed. In the section rather less than a mile above Lochan Fada the mica-schist is mixed irregularly with a coarse gneissose rock containing large crystals of green actinolite, epidote, pink and white felspar, and some quartz, the dark and the pale constituents being sometimes separated in subparallel folia. The actinolites, in the dark parts are sometimes grouped in radiate forms as much as an inch in breadth. These two types of brown mica-schist and coarser gneissose rock are often arranged in parallel bands. The schist sometimes shows a structure resembling bedding, which is crossed by a foliation in the same direction as the banding in the coarse rock. In some places the junctions between the two rocks are much complicated, and parts of the brown rock appear to be included in the other.

The more siliceous mica-schists weather with a pale-grey crust, and often project somewhat from the other mica-schists with which they are associated. When broken across the foliation they show a conchoidal fracture which sometimes presents a vitreous lustre. In Gairloch they never form broad outcrops, and in the mapping of the ground they have not there been separated from the other mica-schists. They may be seen on the west side of the Kerry slightly west of south of Kerrysdale, 200 yards south of Lochan Dubh nan Cailleach (in bands six or seven feet thick), and about 700 yards E.S.E. of Kerrysdale. In the area north-east of Loch Maree siliceous mica-schists are more common. A broad band of them runs close to the path from near Letterewe to near Regoilachy; other exposures are met with east of Furnes and near Coppachy.

A specimen (4196) of the hard mica-schist from the roadside a quarter of a mile south of Meall Aundrary (two and a half miles south-east of Gairloch) was found, under the microscope, to be essentially composed of a fine-grained mosaic of water-clear grains and minute flakes of pale-brown mica, with iron-ore and tourmaline (scarce and in fragments) as accessories. Another specimen (4787) obtained half a mile north-west of Inishglass (on the north side of Loch Maree) contains a number of small pink garnets which are just large enough to be discerned by the hand lens. Garnets also occur in the thin bands of mica-schist interbanded with graphite-schist on the hillside nearly a mile south-west of Beinn Lair.

The more micaceous mica-schists never spread over large areas either in the Gairloch area or in that to the north-east of Loch Maree, and they have not been mapped separately from the others. Half a mile slightly east of south of the foot of the Dubh Loch, Gairloch, the shore of the lake exposes bands composed of crumpled folia of brown and white mica, with idiomorphic garnets, interstratified with more siliceous schists. On the shore of Loch Maree, 150 yards slightly west of south of Inishglass, garnets are also specially abundant in the more micaceous schists. The thin band of altered sediments in the burn east of Meall Each includes a silvery garnetiferous mica-schist, only a few feet thick, which is described by Dr. Teall as a type specimen.

No clastic grains have been detected in any of the mica-schists. In some places, as, for instance, on the shore of Loch Maree, 150 yards slightly west of south of Inishglass, the foliation planes of the schists display many thin quartz-veins in which a white felspar occurs in scattered eyes, which are often thicker than the quartzose parts of the veins in which they occur. Thus, in one of the veins that has an average width of three-quarters of an inch, an eye of felspar was noticed an inch and a half broad. Many of these eyes have only short extensions of quartz at their sides, and might on cursory examination be mistaken for clastic grains. Most of them show one cleavage-plane extending across their whole breadth. The mica-schists have been repeatedly folded. Owing to their fineness of grain, it is difficult to discern to what extent they have also been affected by cataclastic or mylonising action. Microscopic examination shows, however, that in many places the granulitic constituents have been strained and crushed, or broken down into streaks of finer granules. Mylonised structures, where not seen in the schists themselves, are sometimes visible in thin pegmatites within the schists. Examples of such sheared pegmatites have been observed near the thick hornblende-schist a quarter of a mile north-east of Furnes (on the north side of Loch Maree), about 700 yards slightly east of north of Coppachy, and in various places rather more than two-thirds of a mile slightly south of west, and again 1500 yards S.S.E. of Coppachy.

Some of the brown flaggy schists on the south-east side of Beinn Airidh a' Char should probably be regarded as mylonites into the composition of which mica-schist and also other rocks have entered. In a section near the south-west edge of the thick hornblende-schist a mile south-east of the hill-top, the brown schist contains lenticles and eyes of finely foliated hornblende-schist like that of the thick band. Many of the lenticles are two or three feet long, and the folia in them end abruptly at the margins of the lenticles, while the planes of the brown rock wind round the margins.

Mica-schists are occasionally crossed by flinty or halleflinta-like streaks which seem to be due to intense crushing. Examples may be seen about 200 yards east of Regoilachy, about 1500 yards S.S.E., and half a mile north, of Coppachy, and in a band rather more than a mile slightly west of south of Beinn Lair.

(2) *Mica-actinolite-schists.*—Mica-schists with long needles of actinolite are not uncommon. The brown mica and actinolite are frequently accompanied by large garnets, thin calcareous

Lenticles of saussurite in a matrix of Hornblende-Schist, near the summit of Pass, between Letterewe and Carnmore, Loch Maree, Ross-shire.

streaks, and specks of pyrites which give a rusty colour to the weathered surface of the rocks. Thin bands of such schist may be seen in Gairloch at the following places: near the south-west side of the thick hornblende-schist nearly half a mile south-east of Loch Bad an Sgalaig; at the north-east side of the thick hornblende-schist half a mile south-east of the outlet of the Dubh Loch; about 700 yards S.S.W. of Lochan nam Breac; at the north-east side of the thick hornblende-schist 100 yards west of Am Feur Loch, and along the strike north-west. In the area north-east of Loch Maree schists of this type form a considerable proportion of the bands of micaceous-schist which run from near the top of Beinn Airidh a' Char towards the west end of Loch Garbhaig. Examples may also be seen in the burn that flows into Loch Maree about half a mile east of Isle Maree, at the edge of the thick hornblende-schist rather more than two-thirds of a mile slightly south of east of Furnes, in Gleann Tulacha, 350 yards S.S.E. of Strathanmore, about half a mile slightly east of north of Ardlair, and east of Am Marcach.

While in some of these schists the hornblendes are small and sparsely scattered through the micaceous matrix, in others only a few yards distant these minerals may be half an inch broad and two inches long and may preponderate over the matrix, sometimes combining in radiate shapes, with arms nearly parallel to the foliation of the rock and the flakes of brown mica. Macroscopically they are dark-green or black, but in thin slices often nearly colourless, and crowded with small inclusions of granulitic materials. Most of the garnets have rounded edges, or they occur in lumps with their long axes parallel to the foliation. In the band three-quarters of a mile south-west of Beinn Lair, the larger garnets have rounded outlines and coats of biotite, while the smaller have no such coats and are idiomorphic.

These forms of mica-schist include calcareous portions which vary from the thinnest streaks to bands a foot or two thick, and often cross the foliation planes of the rock, or enclose rounded pieces of the schist. In a band within the thick hornblende-schist half a mile south-west of Meall Mheinnidh, north of Letterewe, the transgression of the calcareous streaks and the inclusion of hornblendic parts is well seen. Some of the hornblendic lenticles appear to have been derived from a rock which was first sharply folded and then broken along the limbs of flexure. A considerable proportion of the calcareous matter would therefore appear to have been introduced into its present position either at the time of, or subsequently to, various thrusts and mylonising movements. Some lime may perhaps have been liberated by chemical changes taking place during these movements, for instance, by the conversion of part of the hornblende into biotite. But these rocks were probably originally calcareous, and most of the substance of the calcareous streaks may have been derived from other parts of the bands. The ready solubility of calcite would enable it to travel from one part of the rock to another, and to collect in the lines of thrust.

In a specimen (4761) taken from about 1500 yards slightly west of south of the lochan on Meall Mheinnidh, the schist has been considerably sheared. It contains some large grains of hornblende and of garnet round which the thin laminæ of the matrix sweep. The hornblende fragments show strain shadows, and one of them in the thin slice is crossed by microscopic faults. Some of the garnet pieces are full of cracks which do not go into the matrix and which were probably produced during the mylonisation. In slice 4766, made from a rock two-thirds of a mile slightly east of north of Isle Maree, the grains of water-clear material enclosed in the pieces of hornblende are generally larger than those in the matrix, which may be accounted for on the supposition that they were protected by the enclosing hornblende from the crushing movements. In a schist (4411) observed about 300 yards north-west of the head of Lochan Fada many needles of pale-brown tourmaline can be seen under the microscope, some of them broken and slightly faulted. A few quartz-tourmaline veins have been noticed in the schists on the north-east side of Loch Maree.

(3) *Graphite-schists.*—These form thin bands from a few inches to rarely more than a few feet in thickness, much intermixed with mica-schist or mica-actinolite-schists. The graphite never occurs in distinct scales, but in irregular clots, shreds, and small particles which sometimes exist as inclusions in the other minerals in the schist. In some places these inclusions prove not only that the graphitic rocks existed as schists, but also that these schists had been much contorted and crushed before the formation of the minerals which contain the graphite. One of the common enclosing minerals is actinolite in feathery and radiate forms. The graphite-schist, for instance, which crops out about 1500 yards S.S.E. of Beinn Lair is hard, has a sharp metallic ring when struck, and contains folia particularly rich in graphite, some of which is traceable through the actinolites (4427).

At a locality nearly a mile south-west of the same mountain a dozen alternating laminæ of more or less graphitic schist are sometimes visible within a breadth of half an inch. The extreme thinness of these laminæ, however, may perhaps be due to their having been dragged out in the limbs of a fold. Near Inishglass (on the north side of Loch Maree) and Kerrysdale most of the bands of graphite-schist vary in thickness from a few inches to a few feet: most of the intermixed mica-schists are rather hard and siliceous.

In many of the exposures of graphite-schist numerous slightly-curved surfaces may be seen, perhaps crush-surfaces, which blacken the fingers readily. In some sections, for instance, in the burn a quarter of a mile north-east of Furnes, the graphite-schist is so full of movement lines that no clean fracture can be procured, and yet the schists near it are but little crushed.

The graphitic-schists and some of the mica-schists with which they are so closely intermingled often weather with a rusty colour in consequence of disseminated pyrites. In dry weather the surfaces of these schists are also frequently coated with a thin efflorescence of sulphates. Nearly all the rusty schists between Letterewe and Smiorasair, north-east of Loch Maree, contain graphitic bands, and chiefly lie between hard siliceous mica-schists on the south-west side and a thick hornblende-schist on the north-east. Including thinner hornblende-schists they form an outcrop which varies in width from about 300 yards to a quarter of a mile. Bands of graphite-schist also occur north-west from Loch Garbhaig; 1500 yards S.S.W. of Beinn Lair; at the base of the thick hornblende-schist north-west of Meall Mheinnidh; in Gleann Tulacha; and at other localities.

In Gairloch most of the exposures of graphite-schist lie between the two thick bands of hornblende-schist which run south-east from near Gairloch Bridge and Flowerdale House. Others appear at the side of the new road nearly three-quarters of a mile west of the outlet of Loch Bad an Sgalaig, nearly half a mile S.S.W. of this outlet, rather more than a mile S.S.W. of Kerrysdale, and in a burn a mile and 300 yards south-west of Kerrysdale*.

In a pyritous graphitic rock 230 yards above the foot of the little stream which flows into the Kerry nearly a mile S.S.W. of Kerrysdale, thin veins of biotite-felspar material appear to have been introduced into the rock after it had been brecciated, and the graphite occurs partly as fine dust included in the biotite.

The graphite-schist a mile and 300 yards W.N.W. of the head of Lochan Fada contains a white mica which must have been developed after the parallel arrangement of the chief graphitic portions. In a section (4421) there are also veins and patches of felspar, often twinned, and a mineral, supposed by Dr. Teall to be probably andalusite, which is of later origin than the present distribution of the graphite.

(4) *Granular Quartz-rock.*—Near Lochan Druim na Fearna in the Gairloch area some bands of a granular quartz-rock, pale-pink in colour and somewhat resembling quartzite, have been observed. One of these bands, which appears nearly half a mile slightly east of north of the outlet of the lochan, is about 16 yards broad, and is flanked on the north-east side by thin streaks of similar rock mixed with limestone. Another band, a third of a mile north-east of the outlet, is also rather calcareous in places. The best exposures of this type of rock are to be seen on the south-east of the loch. Each band is there mainly composed of thin parallel laminæ, from half an inch to an inch thick, on the surfaces of which lie scattered flakes of a dark-green mica or chlorite. Some of the bands contain eye-shaped masses, several yards broad, of a dark hornblendic rock, like parts of the adjoining gneiss, round which the laminæ of quartz-rock sweep. If

* For further remarks on the distribution of graphite schist in the Gairloch area, see p. 216.

the quartz-rock is an altered sediment, it would appear to have at one time been made to flow across the folia of the pieces of hornblendic rock. In slice 5122 the junctions of the grains of quartz and felspar are stated by Dr. Teall to be sutural, but this may be due to secondary enlargement of clastic grains.

In the area north-east of Loch Maree similar bands of quartz-rock have been observed on the north side of Amhainn na Furneis, particularly about three-quarters of a mile E.N.E. of Inishglass, and in some scars three-quarters of a mile E.N.E. of Furnes. Bands and lumps of dark hornblendic rock are there also intimately mixed with the quartz-rock, the laminæ of which can be seen in several places to cross the folia of these included masses.

(5) *Quartz-magnetite-schists and Quartz-schists.*—A quartz-magnetite-schist, mixed with limestone and calcareous chlorite-schist, is seen in various places at the north-east side of the thick hornblende-schist which runs north-west from a point 300 yards south-west of the outlet of Loch Bad an Sgalaig in the Gairloch district. The best exposures are by the old road near the south-west corner of the Meall Aundrary wood, and between that place and a third of a mile west of the north corner of the wood. Some varieties of this schist consist of alternating pale and dark layers, the former containing a great proportion of quartz and having a somewhat vitreous lustre, while the dark layers present streaks and irregular grains of magnetite mixed with a little quartz, and affect the compass. The hornblende-schist which runs south-east from Kerrysdale includes various bands of quartz-schist, one of which, rather more than two-thirds of a mile south-east of Kerrysdale, is black and contains sufficient magnetite to affect the compass. Other thin bands of black, or of banded pale-grey and black, quartz-schist may be observed in the following places in the Gairloch district: 250 yards E.N.E. of Kerrysdale; about 700 yards south-east of Gairloch Bridge; nearly a third of a mile north-east, and a third of a mile E.N.E., of the Gairloch Hotel; a third of a mile east of this hotel, and in the apex of a large fold of the rocks about a mile south of Kerrysdale.

Half a mile south-west of Meall Aundrary (two and a half miles south-east of Gairloch), between hornblende-schists, various bands of quartz-schist display a conchoidal fracture, and as some of them contain hornblende they cannot be easily separated from the hornblende-schists of igneous origin.

In the district north-east of Loch Maree most of the quartz-schists, whether with or without magnetite, appear to have been mylonised. They are more compact and more finely banded than those in the Gairloch district, and have a considerable resemblance to banded cherts. The quartz-schists in both districts may possibly represent altered cherts, but the present resemblance of certain portions of them to cherts is perhaps rather the result of deformation. In some exposures north-east of Loch Maree more than 30 thin laminæ may be counted in the thickness of a quarter of an inch. Each of them was not improbably broader originally but has been dragged out and thinned. Most of the outcrops of quartz-schist are only a few feet wide, and the rocks are so much contorted, and perhaps also displaced by thrusts, as to be difficult to trace.

In the inlier of Lewisian rocks on the eastern shoulder of Slioch, near the head of Loch Maree, a thin wedge of altered sediments, exposed in Abhuinn an Fhasaigh, includes, among other rocks, a granulitic quartz-magnetite-schist (4320) which is of special interest, as it contains a mineral supposed by Dr. Teall to be possibly sillimanite. If this supposition be well-founded it would suggest that the rock may have suffered from contact metamorphism, perhaps induced by the igneous rock which is now represented by the overlying thick hornblende-schist (part of the Ben Lair schist).

Quartz-schists with dark-grey or black streaks and resinous lustre are seen at the following places: on the hillside 350 yards north-east of the outlet of Loch Garbhaig; a third of a mile E.S.E. of Letterewe; nearly a third of a mile E.N.E. of Inishglass; a third of a mile N.N.W., and 350 yards slightly west of south of Coppachy; and behind the rock called Torr an Fhithich*, about half a mile north-west of Smiorasair. At the second, third, fifth, and last-named localities the quartz-schist contains small pieces of actinolite-schist and of hornblende, and is closely associated with actinolite-mica-schist. At the second, fifth, and last places the dark colour is known to be due to magnetite. In the fourth the schist is mixed with thin calcareous streaks, and the different folia sometimes strike at one another—presumably at opposite sides of thin dislocations.

Some of the quartz-schists here described may possibly have been produced by the shearing of quartz-veins. The hornblende-schist a mile N.N.E. of Isle Maree is traversed by a folded quartz-schist, about 12 feet thick, containing a good deal of pyrites. At its marginal junction with this schist the hornblende-schist is occasionally replaced by chlorite-schist, and thin bands of similar quartz-schist cross the foliation of the hornblende-schist in a vein-like manner.

(6) *Quartz-hornblende-schists.*—A few bands of quartz-hornblende-schist have been noticed in the broad mass of hornblende-schist on Beinn Lair. About half a mile south-east of the hill-top two such bands, two feet and five feet thick respectively, are separated by 16 feet of fine hornblende-schist, from which they are sharply defined. They both contain crystals of dark-green actinolite, some of which measure three or four inches in length and half an inch in breadth, and coalesce into radiate forms. Idiomorphic garnets, half an inch broad, occasionally occur, particularly in the more micaceous portions of the rock. The quartz, usually subordinate in amount to the

* An analysis and description of the Torr an Fhithich rock is given on p. 80.

actinolite, occurs in granulitic streaks edging that mineral. In a thin slice (5109) examined under the microscope the actinolites are seen to contain many inclusions of quartz. A band of similar schist, about 20 yards wide, may be seen a little more than two-thirds of a mile south-east of the top of Beinn Lair.

(7) *Limestones.*—The limestones are for the most part composed of granules of white calcite together with flakes of mica and with needles of pale-green tremolite, which often form radiate groups. Some varieties, however, contain a considerable proportion of chlorite and seem to pass into chlorite-schists. The limestones are rarely more than a few feet in thickness. The different bands will here be described seriatim, first in the Gairloch and then in the Loch Maree area.

a. Gairloch Area—Shieldaig.—A limestone striking W.N.W. was formerly quarried in the wood a quarter of a mile E.S.E. of Shieldaig. The exposure visible in the quarry is about twelve yards wide, but the bed is evidently much folded and mixed with less calcareous parts, like the calcareous schists on its south-east side. The purer bands consist of coarse white marble with thin green serpentinous patches. About 40 yards W.N.W. of the road the marble contains, near the middle, a pegmatite five or six yards thick. By the road 170 yards north-east of this outcrop a band appears, about a foot thick, with abundant fibres of pale-green actinolite: the carbonate portions of the limestone are of a deep brownish-red colour, probably in consequence of staining from Torridonian breccias. In the wood two-thirds of a mile E.S.E. of Shieldaig four or five bands of marble can be traced, which perhaps all belong to the bed quarried nearer Shieldaig. One contains many parallel fibres of pale-green tremolite, flakes of pale-brown mica and chlorite (?). The calcareous matrix is partly white and partly red, the latter colour being especially common near joints.

On the north-east side of the Torridonian rocks near Lochan Druim na Fearna limestone occurs at several places, and has been quarried at one of these. In an exposure about 700 yards slightly east of north of the outlet of the lochan the limestone is mixed with granular quartz-rock. On the south-east side of the lakelet two bands of limestone crop out, one of which consists of two portions separated by a calcareous hornblende-biotite-gneiss four or five yards wide: the total thickness, including the biotite-gneiss, is about eleven yards.

The Am Feur Loch.—The limestone 260 yards north-east of Am Feur Loch (three miles south-east of Gairloch) gives the name to the hill, Meall an Tuill-aoil (= hill of the quarry-holes of limestone). It is divided into two bands by a calcareous hornblende-biotite-gneiss. The north-easterly band, about 15 feet thick in one place, has been quarried along its outcrop for 70 yards. Both bands are fine grained, of a white or pale-cream colour on fresh fracture, and contain small parallel flakes of a colourless mica and greenish fibres of tremolite. Two sets of planes may be observed in the rock, both nearly parallel to the strike. In one of these the planes are smooth, almost free from mica, and occur at intervals of about half an inch. In the other they lie at greater intervals, and are rougher and more micaceous. In the former case the planes seem to represent thin crush-lines or joints, and to be later than the others. Perhaps they are of the same age as the lines of flinty crush near the north-east side of the thick hornblende-schist of An Groban and Sithean Mor. The north-east side of the double limestone is flanked by a sheared micaceous gneiss. On the south-west side no rock is seen for some distance. Mr Barrow has made the following analysis of a specimen of the south-west portion, from which it appears that the rock is a slightly ferriferous dolomite:—

CaO - - -	32·7 per cent.
MgO - - -	16·2 ,,
FeO - - -	1·3 ,,

The limestone is not seen further north-west, nor nearer in a south-east direction than a mile and 300 yards. This may be due to faulting along the flinty crushes already alluded to. In the exposure to the south-east the limestone makes an outcrop about ten yards broad. It there contains tremolite, brown mica, some soft serpentinous parts and thin bands of a calcareous biotite-hornblende-gneiss which resembles the rock at the sides.

M a g n e t i t e L i m e s t o n e.—About 150 yards east of the outlet of Lochan Dubh nam Biast*, and more than three-quarters of a mile from any other rock which has been mapped as a sediment, a limestone containing magnetite makes its appearance. The greatest breadth of good limestone is about six feet, but there are also other impure calcareous rocks at the side. The carbonate portions weather with a yellow or leaden colour, but in fresh fracture are white or pale pink. They are mixed irregularly with pieces of magnetite, hornblende, epidote, and chalcopyrite, but subparallel zones occur in which the carbonate, the hornblende, and the magnetite are predominant in turn. The carbonate sometimes contains a large proportion of magnetite, which also occasionally constitutes the greater part of streaks five or six inches thick. The hornblende is dark-green or black macroscopically, and occurs both in sheaves several inches long and in small prisms. The epidote is in small green prisms. The chalcopyrite only occurs in small scattered grains. In a slice (4178) of a specimen which is poor in carbonates, the microscope shows that felspar, frequently in a granulitic condition, also forms an important constituent of the rock.

At the edge of this band a hornblende-epidote-rock, which shows no clear foliation, varies in thickness from two inches to a foot. Six or seven yards from the limestone the common red gneiss of the adjacent country comes in, showing subparallel quartz-streaks. The ground between this gneiss and the hornblende-epidote-rock is occupied by material intermediate in

* This is the long narrow loch east of Loch nam Buainichean.

character between these two types, showing fewer quartz-streaks than the red gneiss but a good many lenticles rich in hornblende and epidote.

Bad an Sgalaig.—The limestone which runs north-westwards from a point 300 yards south-west of the outlet of Loch Bad an Sgalaig, along the north-east side of a thick hornblende-schist, is usually mixed with calcareous chloritic schist and quartz-magnetite-schist, and in this mingled condition forms a zone which can be followed for three miles, though for not much more than half this distance are the outcrops of limestone sufficiently thick to be mapped. This failure may be accounted for partly by folding, partly by faulting, and partly by variation in the original character of the rock. Flinty crush-rocks run along the zone for considerable distances.

Limestone in thin bands and streaks mixed with chloritic schist is exposed in the burn 700 yards east of Kerrysdale, but has only been seen in two places further north-west. Along the strike in a south-easterly direction it is more often visible, the positions in which it seems the thickest being now at one side of the chlorite-schist and now at the other. About a quarter of a mile west of the outlet of Loch Bad an Sgalaig a limestone outcrop has a width of two or three yards, and this is perhaps as wide as any.

Copper-bearing Limestone.—On the south side of the old road, nearly a mile and 300 yards south-east of Kerrysdale, a much contorted brown-weathering limestone crops out. It is mixed with talcose streaks and siliceous layers which contain a good deal of pyrite and some chalcopyrite. Its apparent thickness is ten feet, but the calcareous portions of the band are probably less in amount than those of the other constituents taken together. None of the pyritous layers exceeds two or three inches in thickness.

An Ard and Kerry Glen.—Outcrops of limestone, generally of an impure character, have been observed at various places between Gairloch and Dubh Loch. Most of these lie a little south-west of the mica-schists supposed to be of sedimentary origin, and they are bounded by augen-schists which probably represent sheared forms of augen-gneiss.

On the south side of the bay south of An Ard two calcareous bands can be seen, each about four feet thick, while a third, about two feet, appears twenty yards to the south-west of these. The two-foot band is represented again on either side of An Ard. It always has the augen-schist on both sides, and itself contains some small eyes.

The gorge of the Kerry, 180 yards above the foot of the river, exposes a limestone, two feet thick, 50 yards south-west of the mica-schists. On the north-east side the augen-schist appears, and on the south-west hornblende-schist with augen-schist beyond. Less pure calcareous bands also occur close to the edge of the mica-schists, likewise on the south side of Loch Kerry.

PLATE XXIX.

Phacoidal structure in Biotite-Gneiss and pegmatite, produced by post-Cambrian movements. Three-quarters of a mile west of Stromeferry Railway Station, Ross-shire.

At the side of the new road between Kerrysdale and Loch Bad an Sgalaig several calcareous bands, which may be seen a little south-west of the junction of the mica-schists and the augen-schists, all contain much mica, some of them consisting chiefly of mica, or of chlorite, with actinolite in feathery forms. A specimen (4348) examined in a thin slice under the microscope is found to consist essentially of granulitic quartz, brown mica, and calcite. The calcite grains interlock with those of the granulitic constituents.

b. Area North-East of Loch Maree—Letterewe.—The Letterewe limestone is the best known of the limestones*, and perhaps also the thickest. On the west side of the burn 200 yards north-west of the ruined house of Folais it was formerly extensively quarried, and a tramway descended from the quarry to the shore of Loch Maree. The limestone with the calcareous beds that accompany it appears repeatedly in the burn north of the quarry for about 700 yards, the exposures being separated by outcrops of finely foliated hornblende-schist which closely resembles that of Beinn Lair. Here the rocks occupy the apex of a compound syncline, the axial planes of which strike north-west. In some of the exposures the thickness is about 20 feet. South-east of Folais, in the south-western limb of the syncline, the limestone and calcareous beds can be traced nearly three miles. Yet they form here only a thin outcrop, and they are much interrupted at the south-east end by lines of movement. From the outcrop in the burn two-thirds of a mile north of Folais the horizon continues nearly a mile south-east along the north-east limb of the syncline, but the sections are poor.

The limestone of the quarry is compact and creamy and contains lumps of green actinolite. Some bands in it include more biotite, chlorite, and hornblende than carbonate, and display also thin streaks of white talc (?). Some of the actinolite lumps are two or three inches in diameter, and all have smooth rounded surfaces, coated with flakes of biotite, chlorite, or white mica. In cross section some of them show centres from which the actinolite crystals have grown out in diverging rays, while many others are broken by small faults.

A soft greenish rock, which appears to be a calcareous mylonite in a line of movement, is seen between the thick limestone and the hornblende-schist on the east side of the burn near the tramway end. It traverses contorted bands of the massive limestone. It is finely striped, and the long axes of included fragments of other material are parallel to the banding. Its inclusions consist of eye-shaped lumps of limestone, rounded pieces of actinolite fibres (like those in the thick limestone), and of quartz-tourmaline vein-stuff, together with scattered prisms of tourmaline.

* It is indicated in Macculloch's Geological Map of Scotland, and described by Sir R. I. Murchison and Sir A. Geikie in their paper "On the Altered Rocks of the Western Islands of Scotland, and the North-Western and Central Highlands," *Quart. Journ. Geol. Soc.*, vol. xvii., p. 171.

All the impure calcareous rocks which accompany the thick limestone seem to be mylonised, but they are not all of the type of the green rock just described. The mylonised rock close to the north edge of the calcareous zone in the burn two-thirds of a mile slightly west of north of Folais includes many small pieces of finely foliated hornblende-schist resembling the hornblende-schist a little higher up the burn. Other contorted strips of similar schist also appear, varying in length from a few inches to a few yards, the ends of which are cut sharply by the fine laminæ of the matrix. At this locality no lumps of radiate actinolite were observed. The lenticles and pieces of hornblende-schist are most abundant close to the thick hornblende-schist which bounds the mylonised rock. Hence it is probable that the finely foliated hornblende-schists which adjoin the mylonised rock have contributed material towards its formation. The line of junction between the two is in many places a crush line, at the side of which the foliation planes of the hornblende-schist have been truncated. In the burn two-thirds of a mile slightly west of north of Folais, besides the pieces of hornblende-schist, fragments of a slightly calcareous dark-grey mica-schist, very rich in biotite, appear in the crushed material. These become more numerous a little further away from the hornblende-schist, and sometimes form thin strips two or three feet long and several inches broad. A little lower down, the section exposes a calcareous mylonised rock with broken pieces of epidote, and trains of minute granules of that mineral which sometimes wind round the larger epidotes. In a thin slice prepared from a specimen of the rock (4426) one of the longer prismatic epidotes is broken across and faulted, but without any indication of crushing later than the formation of the matrix. This matrix is itself a crush-rock, and the epidote has evidently been broken during the progress of the crushing. Many of the epidotes contain inclusions and bays of water-clear granules of larger size than most of those in the matrix, and these granules have perhaps been protected from the mylonising movements by the epidote around them. The mylonised matrix is fine-grained, and seems to consist largely of minute scales of mica and of microcrystalline quartz and felspar.

The calcareous zone continues to be traceable for some distance in a more or less mylonised condition in both the large limbs of the syncline. Some of the interruptions in its course, and its cessation in the south-east portions of the limbs, may be attributable to lines of movement. The limestone as exposed in the south-west limb of the fold about 700 yards N.N.E. of Coppachy contains small flakes of colourless mica, streaks of a greenish-grey serpentinous substance, and some brick-red bands coloured by small specks of ferrite, which are sometimes arranged in a kind of network. Thin slices of these bands examined by Dr. G. J. Hinde were not considered by him to be of organic origin. On either side of the limestone, and partly folded with it, a massive gneissose rock appears which contains a good deal of hornblende, and about two-thirds of a mile east of Inishglass includes calcareous bands near the limestone.

A limestone, cryptocrystalline and pyritous in places, and accompanied by calcareous biotite-schists, is exposed at several places near hornblende-schist close to Regoilachy and also about a third of a mile W.N.W. of Smiorasair. Most of its outcrops are mere lenticles, but near the last-named exposure the limestone can be traced for a quarter of a mile through several sharp folds. The accompanying calcareous schists contain larger flakes of biotite than the mica-schists.

Gleann Tulacha.—Although the Gleann Tulacha and the Letterewe limestones may possibly represent the same bed in different limbs of fold, they nevertheless differ considerably in appearance. Most of their differences may not improbably be due to the amount of deformation which the Letterewe limestone has undergone. A good exposure of the Gleann Tulacha limestone may be seen on the hillside rather less than a mile W.N.W. of the head of Lochan Fada. The fresh rock is there almost pure white on a fresh fracture, but the weathered surface has a brownish hue and is crowded with projecting fibres of pale-green tremolite, arranged in fan or radiate forms. Individual fibres of the mineral penetrate far into the substance of the matrix and show no signs of crushing. Those of longest dimensions lie in parallel planes and give rise to a banded appearance. In a thin slice prepared from a specimen of the rock (4417) a few pieces of a biaxial untwinned mineral, probably felspar, are disclosed by the microscope. About 300 yards W.N.W. of the good section near Lochan Fada, above referred to, a boulder of limestone has been observed to be crowded with prisms of pale-green augite, but this mineral has not been observed in the limestone *in situ.*

Lower down the glen similar limestone crops out near bands of a contorted pale-pink, quartzite-like rock, which shows on its foliation-planes a good deal of mica and small eyes of felspar. A specimen (4420) of the pink rock was found to consist of irregular fragments of felspar (microcline in part), imbedded in a mylonised matrix of quartz and felspar, with carbonates and white mica as accessories. The parent rock may possibly have been a gneiss, like parts of the rock which appears on the north-east side of the glen. Near the head of Gleann Tulacha several other outcrops of limestone have been noticed. One of these, about half a mile slightly east of north of Beinn Lair, is five or six yards wide, and has a garnet-actinolite-mica-schist on its southern side. The north side is probably flanked by a little graphite-schist followed successively by (1) actinolite-mica-schist, (2) the mylonised pink rock, and (3) the gneiss.

On the north-east side of Meall Mheinnidh four bands of limestone or calcareous rock can be observed within 100 yards of the Beinn Lair hornblende-schist. The two highest bands belong to one bed repeated by a crush that runs nearly parallel to the strike: the bottom band contains streaks and lenticles of marble imbedded in a chloritic or micaceous schist which overlies gneiss. Along the north margin of the hornblende-schist of Beinn Airidh a' Char the limestone appears at intervals, near Strathanmore and in a burn W.N.W. of the top of that hill. In one of the exposures in that stream the limestone contains reddish streaks and patches (3471) which owe their colour to the presence of an abundance of beautiful crystals of yellowish-brown rutile. A plagioclase felspar and quartz are also present.

About 50 yards north-east of the junction of the burns one mile north of Ardlair, an old quarry supplies an exposure of the limestone, which is there mottled green and pink, and includes calcite, tremolite, phlogopite, hæmatite, and chlorite. The mica-plates have often been bent and twisted, and the other minerals show signs of mechanical disturbance. On the line of strike 150 yards to the south-east the limestone is again visible as an almost pure white saccharoid dolomite, bounded on the north-east by hornblende-schist which seems brought against it along a line of fault. An analysis (see p. 82) shows it to contain over 96 per cent. of mixed carbonates of lime and magnesia. In the stream to the southward the limestone may be noticed in four or five places about half a mile south-east of the junction of the burns, but owing to folds and crushes no continuous section can be seen. The highest outcrop, more than half a mile from the foot of the burn, consists of a compact, banded, white and dark-grey limestone, composed of carbonates and chlorite, with here and there a grain of plagioclase intergrown with the carbonate, and some microcrystalline aggregates of quartz. An analysis of the calcareous portion of a specimen (5480) shows it to contain not much more than one-half as much magnesia as the specimen last referred to. The banding in the rock, strongly suggestive of stratification, is due to the concentration of silica along certain lines. The original rock was probably a cherty carbonate.

A quarry has been opened to the west of Am Marcach, near Loch Maree, in a light-coloured micaceous and siliceous dolomite, west of which the limestone, bending sharply round, trends S.S.E. It has a high dip towards W.S.W., and is in some places vertical. Nearly half a mile W.N.W. of the Ordnance station on Am Marcach a lenticle of limestone may be seen by the side of Loch Maree in what seems to be a crush-line parallel to the loch.

L o c h G a r b h a i g.—With an actinolite mica-schist exposed in a burn rather more than a third of a mile E.N.E. of Loch Garbhaig we see a band of limestone, one or two feet thick, which contains in certain layers many small pink idiomorphic garnets and also small flakes of brown mica. These garnetiferous seams weather in retreat from the paler parts of the rock, some of which are mixed with thin streaks of granulitic quartz (4795).

I n i s h g l a s s.—On the south-west side of the thick hornblende-schist a quarter of a mile slightly east of north of Inishglass, and in some other places along the same strike, a dark-brown or almost black limestone with clustered fibres of hornblende is exposed. The hornblende is pale-brown macroscopically, but colourless in thin slices (4799 and 4800), and repeatedly twinned. Most of the rock is crowded with black amorphous grains distributed irregularly.

(8) *Calcareous Biotite-hornblende-schists.* — Many of the limestones are immediately flanked by calcareous schists or gneisses, in which biotite, or a green mica, and hornblende (seldom radiate) occur in abundance. Thus, a wide band, which is poor in hornblende, appears near the limestone in the woods a quarter, and two-thirds, of a mile E.S.E. of Shieldaig, Gairloch. The calcareous-schist and the limestone together make in one place an outcrop not less than 130 yards wide, but the schists are not well exposed. Again, about a third of a mile E.S.E. of Folais, north-east of Loch Maree, 60 or 70 yards north-east of the Folais calcareous horizon, a calcareous biotite-hornblende-gneiss shows a somewhat acid gneiss on both sides.

Bands of somewhat massive biotite-hornblende-gneiss, with a considerable proportion of dark hornblende, may be seen in, and near, a limestone a quarter of a mile south-east of Lochan Druim na Fearna (two and a quarter miles south-east of Shieldaig, Gairloch), also in a band about ten yards wide in the middle of the limestone near Am Feur Loch, and again on the sides of the limestone a mile and a half south-east of the outlet of Loch Bad an Sgalaig. The band at the south-west side of the limestone, a quarter of a mile south-east of Lochan Druim na Fearna, contains augen composed of quartz and felspar. In most parts of the band near Am Feur Loch hornblende is in excess of biotite, but there are some layers, as much as a foot thick, which seem to be made up almost wholly of biotite.

(9) *Kyanite Gneiss.*—Three bands of kyanite gneiss with a north-west strike have been noticed near Carnmore (four miles N.N.E. of Letterewe), one about half a mile east, another two-thirds of a mile north-west, and a third nearly a third of a mile slightly west of north of the old house. These are of special interest, inasmuch as they all lie more than a mile and a half north-east of the strike of the nearest rocks which have been mapped as altered sediments.

The band east of the old house, which has been traced for a quarter of a mile, varies in thickness from 16 to 30 feet and dips N.N.E. at about 45°, both its sides being well-defined. The rock is mostly pale-grey and rather coarser than the contiguous gneiss which is reddish with subparallel streaks of white quartz. In the landscape, however, the kyanite gneiss appears darker than the adjacent gneiss. Near the margin of the reddish gneiss the dip of its foliation is the same as that of the kyanite-gneiss, but further off it becomes more irregular and often almost flat. There are also various thrust-like lines, hading north-east, within the reddish gneiss, which suggest that the kyanite-bearing rock occurs along a line of movement. The kyanite crystals, sometimes two inches long, usually project from the weathered face of the rock. Their long axes and the flat sides of the biotite flakes lie rudely parallel to the sides of the gneiss. One type of the rock contains little else than kyanite and biotite, the latter in large crumpled plates sometimes half an inch long, together with occasional quartz-veins which include kyanite in somewhat larger crystals than usual. In the more common type of the rock quartz is abundant, and felspar has also been observed in the thin slices examined under the microscope.

(10) *Cummingtonite Garnet-schist.*—On the south-west side of a mica-schist, about 700 yards south-west of the outlet of Loch Bad an Sgalaig, in the Gairloch area, a rock which strikes north-west consists mainly of subparallel white threads of a fibrous hornblende (cummingtonite) enclosing small garnets. The band is several yards wide, but cannot be traced far. A bulk analysis of it gives as much as 7 per cent. of manganese oxide, and the analyses* of the two chief minerals—the garnet (spessartite) and the cummingtonite—show manganese oxide in both. The rock may perhaps be regarded as an altered manganiferous sediment.

(11) *Chlorite-schists.*—An impure calcareous band in which chlorite is abundant is seen 300 yards E.S.E. of Auchtercairn (one mile and a quarter N.N.W. of Gairloch), where it forms a depression, twenty or thirty yards broad, between bands of hornblende-schist or hornblende-chlorite-schist. It is a soft shivery schist, weathering with a yellow colour, and showing rods of vein-quartz with their long axes parallel. Chloritic schist is likewise to be seen on the south-west side of the broad mica-schist which passes from the wood near Flowerdale House (Gairloch) to Loch Bad an Sgalaig. It is occasionally accompanied by limestone, quartz-magnetite-schist, or by both these rocks. This band attains a maximum breadth of 50 yards, but is usually less, and sometimes disappears. In a few places certain bands seem to consist almost entirely of chlorite. Examples of this type may be seen a quarter of a mile south-east of Furnes (Loch Maree); in the burn by the road about a mile north of Folais; at the edge of the hornblende-schist about 1500 yards slightly south of east of Strathanmore; and in the more easterly of the two burns three-quarters of a mile N.N.E. of Isle Maree.

(12) *Hornblende-schist and Hornblende-chlorite-schist.*—The thick bands of hornblende-schist which appear at the sides of, or within, the altered sediments form the most rugged scenery in the district, as exemplified in Beinn Lair, Beinn Airidh a' Char, An Groban, Sithean Mor (a mile and a half south-east of Gairloch), and in the wooded ridges and slopes near Flowerdale House and Gairloch Bridge. These bands collectively occupy an area which considerably exceeds that of the altered sediments. In that part of Gairloch which lies south of the Strath and Poolewe road, the two series of rocks

* For these analyses and for a description of the microscopic characters of the rock, see p. 83.

are not unequally divided, but north of that road the sediments are almost entirely covered by the Torridonian rocks, while the harder and more prominent hornblende-schist which rose into hills even in pre-Torridon times has been laid bare by denudation, so as to protrude through the sandstones in several areas, one of which, including Cnoc Breac (five and a quarter miles north-west of Poolewe) and Meall Imireach (four miles W.N.W. of Poolewe), is more than three miles long and averages more than three-quarters of a mile broad. In the extreme south of Gairloch also, inliers of hornblende-schist form prominent features some miles from the nearest exposures of the altered sediments, though the latter may possibly lie hidden under the cover of Torridon Sandstone.

The general distribution of these bands of hornblende-schist can best be understood from the maps (Sheets 91 and 92).

In Gairloch the most prominent of them is that of An Groban-Sithean Mor, which is sometimes half a mile broad, and forms the north-eastern margin of the main sedimentary area, though a few thin actinolite-mica-schists appear on its north-east side. The thick parallel bands of hornblende-schist which lie further south-west vary in number and breadth, but become fewer, though broader individually, in a north-west direction. A quarter of a mile west of Loch Bad an Sgalaig four of these parallel bands may be seen, while near Kerrysdale there are two bands averaging each 200 yards in breadth. On the north-east side of the Flowerdale Glen fault there is only one parallel band, but this is about half a mile wide, and gradually approaches the An Groban outcrop in a north-westerly direction till in the Meall Imireach inlier they coalesce, the mica-schist between them having meanwhile wedged out. It may be surmised that all these outcrops may really be portions of only one band which has been repeated by folding. If this be the true structure of the ground the north-eastern margin of the most easterly hornblende-schist at Kerrysdale will correspond to the south-west margin of the Sithean Mor hornblende-schist. The sediments are not the same at each of these margins, but this might be accounted for on the supposition that the igneous rock from which the hornblende-schist was formed was transgressive.

In the area to the north-east of Loch Maree the most prominent band of hornblende-schist of the whole district rises into the rugged mountainous masses of Beinn Lair and Beinn Airidh a' Char. It stretches for eight miles from north-west to south-east, and mounts up to a height of 2817 feet. The breadth of this huge mass on Beinn Lair is about a mile, but other outcrops of similar schist on its south-western side are only separated from it by thin strips of altered sediments. On Beinn Airidh a' Char one may walk almost entirely on hornblende-schist across the usual strike for a distance of about two miles. In doing so one crosses the limbs of a synclinorium with axial planes striking north-west. Hence the base of the band changes its course on the north-west side of Beinn Airidh a' Char, and curves southwards to Loch

Maree, while the hornblende-schists on the south-east slope of this hill are repeatedly folded with a band of mica-schist. Near Folais a broad outcrop of hornblende-schist which lies between the mica-schist just alluded to and the limestone and calcareous rocks is also folded by the syncline and disrupted along its edge by mylonising movements.

The inlier of Lewisian rocks on the eastern shoulder of Slioch is mainly composed of hornblende-schist, which is no doubt an extension, in a south-eastern direction, of the Beinn Lair schist.

There can be little doubt that the hornblende-schists now under consideration were originally intrusive igneous rocks. Portions of them resemble the sheared basic dykes. Their general unifomity of composition and texture and the rarity of inclusions in them which can be regarded as detached fragments of other rocks, or distorted amygdules, are hardly consistent with the supposition that they are altered contemporaneous lavas, but, on the other hand, they have nowhere been observed to transgress the sediments in any clear section. In general they are more finely foliated than most of the dykes, either near them or elsewhere. At various places their margins can be traced for distances, varying from one to three miles, parallel to certain beds in the series of altered sediments. Thus, between Flowerdale and Loch Bad an Sgalaig the margin of one of these bands keeps to the horizon of the quartz-magnetite-schist and limestone for about three miles. Between Letterewe and Regoilachy (Loch Maree) another band continues near a hard siliceous mica-schist for nearly a mile. A similar want of evidence of intrusion is, however, found at the sides of various thin bands of hornblende-schist, which are regarded as dykes which have been sheared and dragged in an unusually intense degree.

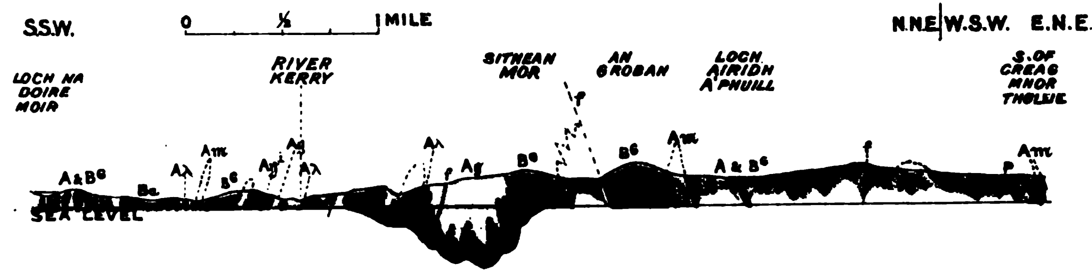
It is improbable that these hornblende-schists can be older than the basic dykes in the gneisses of the Fundamental Complex, for they are never intersected by these dykes, even in places where the adjoining gneiss is repeatedly traversed by them. Perhaps these hornblende-schists represent intrusions which were fed by dykes. Before the shearing of the dykes into schists, the gneiss probably contained few divisional planes compared with the bedding planes of the sediments, and a mass of molten rock which had come up almost vertically through fissures in the massive gneiss might perhaps, on reaching the sediments, find more ready passage between the planes of stratification and take the form of sills. No clear union of a basic dyke with any of the thick hornblende-schists has been seen, but in a good many places the margins of these schist-bands are lines of powerful movement, which may partly explain the want of parallelism* occasionally observed between these bands and the neighbouring dykes.

The most common type among the hornblende-schists associated with the altered sediments is a very finely foliated dark-green schist, in which the crystals of hornblende are

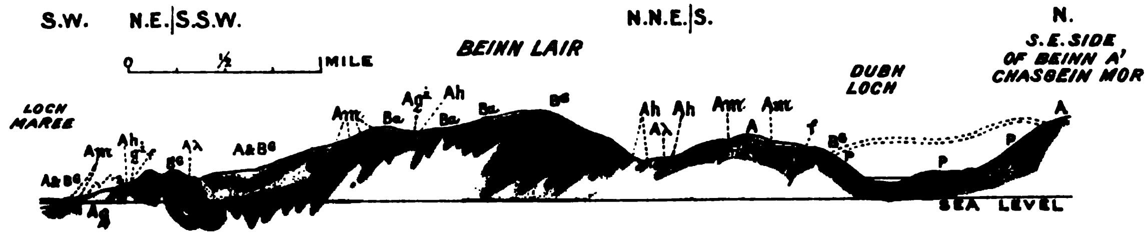
* See p. 216.

Plate XXX.

SECTION, A, FROM NEAR SHIELDAIG, ACROSS GAIRLOCH AREA, TO NEAR THE FOOT OF LOCH MAREE.



SECTION, B, FROM NEAR FURNES, LOCH MAREE, TO BEINN A' CHÀISGEIN MÒR.



A—Gneiss of Fundamental Complex. Ag—Mica Schist. A_g^1—Graphitic Schist. Ah—Actinolite Mica Schist.
Aλ—Limestone. B^e—Epidiorite & Hornblende Schist. P—Pegmatite. Am—Mylonized rocks & Pre-Torridon crush-Lines.
Ba—Torridon Sandstone. f Faults.

879. S. 87. Weller & Graham, Ltd. Litho. London.

needle-like and so minute that they can hardly be distinguished by the unaided eye. These crystals lie on the parallel planes of foliation, but their orientation is variable, though it is usually in one direction—that of stretching. This is the type of rock which was described by Dr. Hicks and Mr T. Davies from the Falls of the Kerry*. Thin layers of different colours usually lie parallel to the foliation, some being almost black, others dark-green, and others a dirty white. In many places these layers are sharply folded or broken by numbers of thin thrust-like lines. The thin slide (3746), prepared from a finely foliated hornblende-schist on the north-east side of Loch Bad an Sgalaig, shows under the microscope that the rock consists of green hornblende, felspar in allotriomorphic and mostly water-clear grains, epidote, calcite, and a few grains of sphene. A few thin lenticular folia are composed solely of granulitic felspar (? albite) and idiomorphic epidote.

It is not clear why the most finely foliated type should also show the best banding. There may have been more segregation during the shearing, or the various bands may have been derived from parts which already differed in general colour before the deformation. On the latter supposition it may be inferred that the rock near the interior of a band was sometimes of a more uniform character than that at the sides.

In another less common variety of these schists no distinct colour-banding appears. The specks of white felspar have their long axes parallel, and help to define the foliation, but they are equally abundant through considerable thicknesses of rock. This type, which resembles the most common form of schist in the basic dykes, is well seen near the middle of the band on Sithean Mor. Two other varieties are common in certain areas; one coarse in grain and showing so little foliation that it may be called epidiorite; the other, a shivery schist, containing more chlorite than hornblende. The massive or poorly-foliated type has only been noticed in that portion of the An Groban-Sithean Mor outcrop which lies east of Loch Bad an Sgalaig. It passes gradually into the foliated variety which is without colour banding, and forms one or more zones near the middle of the band. One of these zones is about 70 yards wide.

Near Kerrysdale chloritic schists occur on both sides of the more north-westerly of the two hornblende-schists. Further to the north-west the broad band of hornblende-schist at Auchtercairn is mixed throughout with chloritic schists, containing small needles of hornblende on the foliation planes. These schists merge into the hornblende-schists. Frequent sharp flexures in the chlorite-schist show nearly vertical axial planes, parallel to which the flakes of chlorite are often arranged. Thin quartz-veins, often disposed in folds, likewise small crystals of magnetite and calcareous spots and streaks, appear more commonly in the chloritic than in the hornblendic schists. The chloritic schists usually effervesce freely with hydrochloric acid, even when no

* *Op. cit.*, p. 108.

carbonate can be recognised macroscopically, and one of the calcareous streaks near Auchtercairn is a good limestone. Near Kerrysdale many specks of ferriferous carbonate, about the size of peas, have been observed, with their long axes parallel to the foliation planes of the chlorite-schists: these are not due to decomposition near the weathered surface, but form an essential part of the rock. It is doubtful whether the thin streaks of limestone, an inch or two thick, occasionally found in the hornblende-schists, represent segregations formed during the shearing process and the change of a lime felspar into albite, or whether they are relics of sedimentary beds incorporated in the igneous material during intrusion or movement. Examples of these calcareous streaks may be seen about 700 yards south-east of Gairloch Bridge, close to the north-east margin of the hornblende-schist, and in a schist on the north side of the path about half a mile south-west of Regoilachy, Loch Maree.

The abundance of carbonate in the chloritic schist is perhaps due to chemical changes during the alteration of hornblende into chlorite, which may have taken place during renewed contortion after the rock was already in the form of hornblende-schist. The chlorite-schists are sharply contorted, and many of them lie along the margins of the sills of hornblende-schist—in positions where they would be peculiarly exposed to shearing movements. That the abundance of chlorite in the thick band near Auchtercairn, Gairloch, may be due to intense shearing is suggested by the changes in structure along the course of the An Groban-Sithean Mor band, which indicate that the shearing in this district increased in intensity in a north-westerly direction, as far at least as the road between Strath and Poolewe.

The thick hornblende-schists are in certain places richly garnetiferous, the garnets being sometimes bordered with granules of white felspar like those common in the foliated basic dykes.

In the area lying to the north-east of Loch Maree the broad bands of hornblende-schist chiefly consist of the finely-foliated type. No parts of them have been observed to be free from foliation, but the shivery chloritic type is rarer here than in the Gairloch area. Examples of the less finely-foliated varieties occur in the following places: on the north side of Loch Garbhaig, half a mile N.N.E. of this loch, between three-quarters of a mile, and a mile, W.S.W. of the summit of Beinn Airidh a' Char, and between the two burns about 700 yards north-east of Am Mareach. The rock at the last-mentioned place is an imperfectly schistose epidote-amphibolite, medium-grained, dark in colour, composed of hornblende and granular aggregates of felspar which are often crowded with small grains and crystals of epidote (5491).

Thin zones in which the hornblende forms augen may be seen in the Beinn Lair schist half a mile slightly north of east of the foot of Loch Garbhaig, a third of a mile slightly north of west of Beinn Lair, and at other places. Here and there, as in the ice-polished scars on the north side of the road by Loch Bad an Sgalaig, small streaks and pieces of felspar probably represent granulitised phenocrysts. In the Beinn Lair schist also an exposure, by the east side of a small burn rather more than three-quarters of a mile east of the head of Lochan Fada, shows a good many imperfect lath-shaped sections of felspar, about half an inch long.

In Beinn Lair and Meall Mheinnidh certain zones contain lenticles of a dirty white opaque substance, which may be noticed at frequent intervals from about two-thirds of a mile east of Strathanmore to three-quarters of a mile S.S.W. of the head of Lochan Fada. Perhaps they are best exposed 200 yards east of the path nearly two miles N.N.E. of Letterewe pier, where the most northerly zone includes several bands, from one to three feet thick, of finely-foliated hornblende-schist enclosing the white lenticles referred to. Of these lenticles, which are sharply defined and project from the weathered faces of the rock, a considerable number are more than a foot long, while some exceed three feet. Their long axes lie parallel with each other and, in these exposures, nearly at right angles to the strike of foliation, although at other places the direction of elongation is different. On the average, the long axes are three times as long as the widths along the foliation, and eight or nine times as long as the width in a direction at right angles to the foliation. The lenticles are sometimes so crowded that they exceed in aggregate amount the matrix of hornblende-schist which lies between them, but they are of irregular occurrence, and the different horizons in which they occur cannot be traced far without interruption. In slice 4423, prepared from one of the lenticles near the path, the only constituent definitely recognisable is epidote in short and slender prisms. The matrix is almost opaque, and the rock is considered by Mr Teall to be a variety of saussurite. (See Plate XXVIII.) The schist containing the lenticles is not crossed by many strain-slips, and there is no reason to suppose that it is more crushed than the adjoining schist. The lenticles are rare in places; indeed, an isolated instance was recorded at a distance of 60 yards from any others—a mode of occurrence hardly explicable on the supposition that they have been produced by the breaking up of a once continuous band. More probably they represent concretions in the igneous rock before its conversion into schist. They may have been originally nearly spherical, and analogous to spherulites; occasionally, indeed, as at a place one-third of a mile slightly east of south of the head of Lochan Fada, examples of them have been noted which give nearly circular sections.

Many of the thin quartz veins in the hornblende-schists north-east of Loch Maree contain tourmaline, of a black tint, in extremely thin needles, which are often combined into sheaves. It usually forms only a small proportion of each vein, the rest consisting of quartz, or of quartz, axinite, and epidote. Such veins are seen on Meall Mheinnidh, from 150 yards north-west of the hill-top to rather more than a quarter of a mile south-east, also 700 yards north-east of the big island in Loch Garbhaig, where some of the tourmaline crystals are an inch long. The axinite, which does not possess good idiomorphic outlines, is of a pale yellow, or sometimes of a faint pink, colour, and generally exceeds the tourmaline in quantity, forming pieces an inch or more in width. Again, in the quartz-veins exposed three-quarters of a mile south-west of Beinn Lair, where large bundles of thread-like crystals of tourmaline occur, these are sharply contorted along folds which have their axes placed almost at right angles to the general direction of the threads. Such indications of movement after the formation of the tourmaline prepare us to find the broken bits of tourmaline vein-stuff which occur in the Folais mylonised rocks*. The occurrence of rounded pieces of finely-foliated hornblende-schist in the Folais rocks, together with the frequent truncation of the foliation planes of the hornblende-schists by these rocks, prove the schists to have suffered considerably from mylonising movements, although not many mylonites appear to have been formed from hornblende-schist alone.

Within the sedimentary zone north-west and south-east of Smiorasair bands of a compact, hard, black flinty-looking rock show under the hand-lens no recognisable minerals except hornblende in a fragmentary form. This material appears to have been subjected to some process of complete reconstruction, presumably by crushing. It occupies the same position in the series as the hornblende-schist, and seems to have been mainly derived from it.

Near Torridonian rocks the hornblende-schists are often crossed by thin epidotic strings, and the foliation planes and the sides of the veins of quartz and pegmatite are also stained with hæmatite. The pebbles in the basal Torridonian breccias are sometimes crossed by epidotic strings, which, as they do not pass into the matrix, must have existed in the Archæan rocks before the formation of the conglomerates. They were doubtless formed in pre-Torridon time by decomposition near the rock-surface. On the north side of the burn about a mile E.S.E. of A' Chosag (two and a quarter miles W.S.W. of Slattadale) a steeply inclined hornblende-schist is intersected by epidotic strings, many of which are nearly horizontal (perhaps rudely parallel to the pre-Torridonian rock-surface) and cut the earlier quartz veins. They often contain quartz as well as epidote, but some are entirely composed of grass-green needles of epidote, often about half an inch long.

(13) *Hornblende-schists with Brown Mica and Pyrites.*—Many of the thin bands of hornblende-schist within the area of the altered sediments have a close resemblance to some of the actinolite mica-schists. They contain calcareous streaks, brown mica, and pyrites, together with hornblende crystals which are

* See p. 233.

frequently arranged in radiate forms, and are of a stouter build than those in most portions of the thick bands. The thin bands of hornblende-schist which occur in the north-eastern portion of the crushed mica-schist, half a mile E.N.E. of Regoilachy, belong to the finely-foliated type so common in the thick bands, and probably some, if not all, of them may represent folded or faulted portions of thick bands. Most of the other bands further to the west, likewise most of the thin bands between Regoilachy and Letterewe, half a mile W.N.W. of Coppachy, and in some other places, belong entirely or in part to the type of schist under description. In Gleann Tulacha pyritous biotite-hornblende-schists appear again near the base of the Beinn Lair hornblende-schist, at the head of Lochan Fada, two-thirds of a mile above the loch, and in some places near the north-east side of the sediments. In the Gairloch district schists of this type are rare excepting near the south-west margin of the Bad an Sgalaig belt of mica-schists.

A slide cut from specimen 4773, from an exposure of these schists at the loch-side 350 yards west of Inishglass, when examined under the microscope proved to be in a mylonised condition. A portion with rounded outline and less calcareous than the rest is a hornblende-schist of finely-foliated type. The rest is composed of streaks which sweep round the edges of this schist.

(14) *Actinolite-schists without either Quartz or Felspar.*—In the mica-schist about 1000 yards slightly east of south of the Dubh Loch (three miles south-east of Gairloch) and near a finely-foliated hornblende-schist three bands, one of them 25 yards wide, consist almost entirely of confused aggregates of small pale-green actinolite needles (5130), and weather with brown and rounded surfaces.

PRE-TORRIDONIAN MOVEMENTS.

As in the district between Scourie and Kylesku, so in the ground described in this chapter, many of the movements which led to the first production of foliation in the basic dykes proceeded parallel to these dykes, sharply contorting the early broad banding in the older Archæan rocks, and giving them a north-west strike. A feature of special interest in the present district is the evidence which it affords that subsequently to these movements, folds, of a comparatively gentle character, were developed which plicated the already partly-sheared dykes, and led to the further foliation of some dykes which were not previously sheared throughout. (See Plate XXVII.) Another noteworthy characteristic here is the development of "rodded" structure both in the gneiss and intrusive dykes. In some rocks the constituents have been thrown into the form of rods and in sections at right angles to the lengths of the rods show no parallel arrangement, as may be specially observed near the centres of the large folds by which the basic dykes have been plicated, for instance, near the centre of the broad anticline south-east of Loch Tollie, and a mile and a third S.S.W. of Beinn Lair. This structure is evidently of secondary origin and due to causes which have affected diverse varieties of rocks over considerable districts. Where the acid-gneisses are rodded, the other gneisses are found to be in the same condition. The basic dykes are sometimes rodded in these areas, but elsewhere they show plane-parallel foliation. This peculiar structure is well represented in Plate XXVI., which is taken from a photograph of part of a cliff-face, five-eighths of a mile north of Meall an Spardain, Poolewe.

A quarter of a mile N.N.W. of Loch Doire na Herrie (three and a half miles E.S.E. of Gairloch), where the acid-gneiss has been sharply folded, it has been changed in places from a rodded into a finely-foliated condition with the divisional planes almost vertical and striking north-west. In the rodded parts it is sometimes hard to distinguish any broad early folia, but those which can be discerned incline south-eastward. The rods dip in the same direction. Near the places where the fine vertical foliation is seen, the broad early folia change their strike and become much thinner, while the granules of quartz and felspar are less in size and more elongated in a direction parallel to the foliation. The influence of the rodded structure on the topography of the ground is well illustrated in Plate XXV., which gives a view of the landscape a quarter of a mile to the north-east of Meall an Spardain, Poolewe.

Similar variations in dip and strike are common in other parts of the folded area south-east of Loch Tollie. Most of the gneiss in the central parts of the anticline shows only an obscure foliation, older than the intrusion of the dykes. The early folia where recognisable are generally broader than those in the steep south-west limb, and often nearly flat or rolling irregularly. But in spite of the attenuation in this limb the gneisses there are not always thoroughly granulitic. If the observer crosses in a south-west direction from the centre of the anticline to the thick hornblende-schist near Loch Airidh Mhic Criadh (a mile and a half north-east of Gairloch) he can readily notice the differences between the obscurely and the closely foliated gneisses. In addition to these differences, it is observable that thin quartz veins, from half an inch to six inches thick and with occasional specks of red felspar, are much more abundant in the limb of the fold than in the centre. The basic dykes in the former show fewer evidences of intrusion than in the centre, which is probably due partly to the great drag which the different rock masses have received in this limb, and partly to the development of a strong second foliation that has obscured the earlier foliation of the gneiss. As in other districts, the second foliation in the gneiss is here always parallel to the foliation in the dykes, and generally parallel to their sides.

Mixed with the more massive gneiss near the centre of the Tollie anticline some thin zones of finely-foliated and yet gently dipping gneiss appear, which must have acquired their structure before the time of the great folds that plicated the basic dykes As a rule these early lines of shear have proceeded along the sides of the dykes. A good section of one of them may be seen two-thirds of a mile slightly north of east of the outlet of Loch na Larach, $2\frac{1}{4}$ miles north-east of Gairloch. In the upper part of this section the early bands of the gneiss are nearly vertical but broad. In the lower part they suddenly twist into a horizontal position, parallel to a thin basic dyke, while at the same time they become much thinner, so as to show hardly a third of the breadth which they have when vertical. The quartz and felspar granules in the horizontal bands have also been attenuated and elongated in a direction parallel to the sides of these bands. Where still broad the bands are crossed by a weak second foliation parallel to the axial planes or twists, but where thinned they seem indistinguishable in structure from those in the south-west limb of the anticline, though they were probably altered before most of those in this limb. The basic dyke is foliated parallel to its sides, in consequence, presumably, of the same movement which modified the gneiss near it. Sections of this kind show that parts of the gneiss in the limb may have been altered before the dykes were folded, but the general contrast in structure between the gneiss in the limb and that near the centre of the fold must be due to alterations which accompanied the formation of the anticline. Plate XXIV. represents the structures shown by the fine-grained biotite-gneiss in the south-west limb of the Loch Tollie anticline.

In the folded area about a mile and a third S.S.W. of Beinn Lair the biotite-gneiss with felspar augen frequently shows no plane-parallel foliation, but is well rodded throughout. Where the dykes strike N.N.E., the direction of the rods is usually almost at right angles to that strike, with a south-easterly inclination at about 20°. Some sections in this ground suggest that a rodded structure may have resulted from movements which elsewhere produced a plane foliation. The minute contortions and strain-slips, which in folded areas have acted on banded rocks, may cut the bands into thin strips or rods, which run parallel to the axial planes of the large folds affecting the rocks. The rods must also incline in the same direction as the broad bands or early foliation, since it is from these bands that the rods have been formed. There are, however, certain areas—for instance, on the shore of Loch Maree, a mile W.N.W. of Ardlair —in which, although the rocks are well rodded, they display no certain proof of having been folded.

Many mylonised rocks have been formed since the first foliation of the basic dykes. In all the thick bands the mylonised laminæ are affected by many thrusts or faults, as well as folds, and these laminæ are frequently broken and faulted as well as folded.

Those which have been formed from the gneisses* are best

* Mylonites formed wholly or in part from the altered sediments and the thick hornblende schists are described in connection with these rocks.

developed between Folais and Fasagh, in the area in which the other mylonites are also most conspicuous. They also appear in various parallel bands which run from a mile and 700 yards south-west of the summit of Beinn Lair to the west end of Loch Garbhaig. Most of the bands do not exceed a few yards in thickness, and at least six may be observed in a breadth of a quarter of a mile. Here the folia are thinner and more sharply folded than those of the adjacent gneiss, and in some places resemble crumpled leaves of paper. They are crossed by a number of thrusts, and in various places are mixed with thin strips of hornblende-schist which have been broken off from adjoining basic dykes. Some of these mylonites may have been formed from pegmatites, but the edges of others seem to pass into the biotite-gneiss at their sides. East of the burn a mile and 200 yards S.S.W. of Beinn Lair a mylonite, about 40 yards wide, has been formed in part from an acid gneiss containing basic streaks and lenticles. Some of the streaks no doubt belong to the Fundamental Complex, but others may represent dykes. The mylonised rocks formed from the acid gneiss have a conchoidal fracture and are of a dark brown or black colour when fresh, but they weather with a dirty white crust, and contain white or pink eyes of felspar. Those which have been produced from the basic streaks intermixed with the acid gneiss do not differ much in character and colour of fracture, but they weather with black or dark brown surfaces.

Specimen 4774 of the mylonite, composed of alternating strips of grey and dark brown colour, from the west side of the burn just alluded to, shows under the microscope well-marked augen. Those in the paler strips are mostly of felspar, and those in the dark bands of hornblende. Some of the augen show signs of crush, and the fine streaks of the cryptocrystalline matrix wind round them, and are sometimes also contorted and crossed by small faults. Mr. Barrow has analysed a portion of this specimen with the following result:—

Silica - - - -	60·3
Alumina - - - -	15·3
Ferric Oxide - - -	10·7
Lime - - - -	5·6
Magnesia - - - -	1·30
Potash - - - -	1·7
Soda - - - -	3·3
Loss on ignition - - -	1·1
	99·3

The percentage of silica must be much higher in some of the bands than in others.

Many of the flinty streaks which occur in the crushed and mylonised bands have probably been formed in the latter stages of the movements which affected the rocks, and are of a somewhat different type from the common mylonites, but they are all considered to be, and many of them can be proved to be, of pre-Torridonian age. Thus the zone of this material which flanks the north-east side of the An Groban-Sithean Mor hornblende-schist does not cross the Torridonian breccia near Loch Airidh Mhic Criadh, though some of the breccia lies in the direction of the main crush. The Flowerdale Glen fault, which shifts the outcrop of this zone, is also of pre-Torridon age. Part of the fault-rock, about three feet across, is seen on the coast 200 yards south of Gairloch Free Church, where it contains various kinds of black and green flinty material. Although the Lewisian rocks near these strings are much twisted, the Torridonian breccia about 200 yards W.N.W., and close to the direction of the fault, is uncrushed and undisturbed. It also contains various compact green pebbles which closely resemble some of the strings in the fault-rock.

Again, about 1000 yards north-east of the outlet of Loch a' Bhealaich (about six and a half miles S.S.E. of Gairloch) the Torridonian breccia, which is seen a few yards off the flinty crush-lines at the south-east boundary of the Lewisian area, has not been disturbed and contains pebbles, some of them eight or nine inches long, which consist of a reddened acid gneiss with black flinty streaks like those in parts of the crush-zone. Other instances might be adduced from Gleann Tulacha and Fasagh, north-east of Loch Maree, where these crush-lines strike at the undisturbed Torridon strata, and where pebbles of the flinty rocks are found in the basal breccias.

In the most compact and flinty crush-rocks no mica can be discerned with a hand lens. The weathered surfaces show a close streaky structure, the streaks being often interrupted by lines of fault, and those in one portion of them striking at those in another, so that the rock as a whole has a less streaky appearance than most of the mylonised rocks. Many hand specimens show no distinct eyes, and do not betray the nature of the parent rock, but in field exposures the flinty rock is always seen to be mingled with other less-altered material. The broad bands shown by yellow lines on the one-inch map (91) are not entirely of flinty rock, but zones in which there is a special abundance of flinty streaks.

Flinty crushes particularly abound on the north-east side of the An Groban-Sithean Mor hornblende-schist, where a zone, usually consisting of several bands that do not keep strictly parallel, runs along nearly the whole of the band, excepting for about a mile near and south-east of Am Feur Loch. It has been shifted for nearly three-quarters of a mile by the Flowerdale Glen W.N.W. fault, which is also accompanied by flinty crushes. Another still thicker nearly parallel zone runs from a little west of Tollie Farm to near the shore of Loch Maree south-east of Doire. Between these two main zones various other bands run in different directions. The areas south-west of the An Groban-Sithean Mor schist contain comparatively few flinty crushes.

Besides the black crush-streaks, the same zones occasionally present dark-brown, grey, or black strings, rarely more than an inch thick, which do not displace the folia crossed by them. These strings sometimes bulge out in rounded projections, or end bluntly and look like intrusive felsites. They are, however. confined to zones which have been crushed, and it seems probable that many of them are isolated on all sides by the adjoining rocks. It is difficult to see how they can be intrusions of true igneous rock. Perhaps by the intensity of the crushing near them sufficient heat may have been generated to fuse small portions of the rock*.

A band of much-crushed gneiss striking north-west in the wood on the north-west side of the Loch Maree Hotel, Talladale, contains various black felsite-like strings which behave as if they were intrusions. In a thin slice, 5270, the substratum of the rock gives an obscure microcrystalline reaction, and resembles certain felsites. It is unlike any rock yet recognised as a product of crushing. Irregular fragments of quartz and felspar lying in this substratum show unmistakeable signs of deformation. Again, just below the summit of Meall Riabhach, Smiorasair, felsite-like strings, varying from mere threads to about three inches thick, are excellently exposed at intervals in a zone about three yards thick. They cut the gneiss in all directions. In one place only, near the east end of the zone, do they show macroscopically any structure like that of a mylonite. The gneiss is clear, fresh, and granular up to the edge of the veins, but there are dislocations near by. A specimen, 4281, of one of the strings shows under the microscope a microlitic structure in the ground mass, and some signs of fluxion. The fragments of quartz and felspar included in the ground mass show strongly-marked cataclastic structures.

Other faults which are not accompanied with mylonites or flinty crush-rocks can also be proved to be of pre-Torridonian age, as, for instance, the one that runs south from about 230

* Mr. Holland ("The Charnockite Series," *Mem. Geol. Survey of India*, vol. xxviii., Part II., p. 198-202) has described gneiss with strings and tongues of a black compact character which look macroscopically like injected basic material. These had originally been taken as igneous rocks, and the gneiss in which they occur had been called trap-shotten gneiss. Mr. Holland states, however, that the black substance has, under the microscope, no igneous structure; it is composed of a black dust through which angular fragments of quartz and other transparent minerals are disseminated, and the whole rock is highly crushed, with the production of mylonite and frequent microscopic faulting. The rocks around being often acid in composition, the black colour of the mylonite strings is a matter of surprise. The bands under the microscope include innumerable minute opaque black bodies which suggest sublimation by heat, or introduction of material in solution. Examination of very thin slices seems to show the beginnings of crystallisation in the black dust. Sometimes shallow bays in the quartz-pieces are filled with the black dust, as if corrosion had commenced. These phenomena indicate that the rock has been greatly heated, but not to so high a temperature as to fuse the dust completely. Mr. Holland crushed a specimen of acid charnockite and heated the powder to a white heat, sufficient to produce a very imperfect fusion ; the result was a fritted black cake.

yards west of the outlet of Lochan Druim na Fearna, and is covered by an outlier of undisturbed Torridonian breccia.

The old lines of movement which existed before the Torridon Sandstone was laid down have in some places been used again in post-Torridonian time.

GNEISS AFFECTED BY THE POST-CAMBRIAN MOVEMENTS.

Above the Kinlochewe thrust-plane, Lewisian rocks reappear in various isolated parts of this district, all of which, with one exception, are of small extent. The structural relations of these masses will be described in the section dealing with the post-Cambrian movements (Part IV.). Attention is here called to the petrographical characters of the largest and most important mass that lies north of Kinlochewe. Measuring seven miles in length from north to south, and about three and a half miles in breadth, it covers an area of about twelve square miles.

As already mentioned, Professor Bonney recognised the petrographical characters of some of the rocks of this displaced mass, and noticed the presence of a rather granitoid variety of the Hebridean gneiss, the occurrence of dykes, and of a green schist with marked fragmental structure due to crushing*.

This detached portion of the Fundamental Complex contains knots, lenticles, and larger masses of ultra-basic and early basic material, which, in some cases, show a banded arrangement of the constituents that must have been developed, in part at least, before the injection of the later more acid gneiss. Some of the early basic parts are about half a mile in diameter, and consist of hornblende-gneisses and amphibolites. The most characteristic feature of the whole outlier, however, is a coarse granitoid gneiss with biotite, and showing rude banding. This rock invades and isolates the older basic portions of the mass, and, save near the thrust-planes, has been little deformed by the post-Cambrian movements. Northwards from the Heights of Kinlochewe, beyond Gleann na' Muice, in the Pass of Beallach Bhain, that leads to Loch an Nid, this type becomes a gneissose granite, and in places shows no banding at all, consisting of plagioclase, orthoclase, microcline, quartz, and chlorite after biotite, and showing a strong resemblance to the older part of the Fundamental Complex south of Gruinard in the undisturbed area to the west (Chapter XI.). Over much of the tract the foliation planes roll about at low angles, but near the Heights of Kinlochewe their strike is north-west.

Another noteworthy feature is the occurrence of numerous dykes of epidiorite that traverse the gneiss in a W.N.W. or north-west direction, and show their intrusive character as clearly as in the typical area between Scourie and Loch Inver.

Plate II., which represents a portion of this displaced mass, shows two epidiorite dykes intersecting the rudely-foliated

* *Quart. Journ. Geol. Soc.*, vol. xxxvi., p. 93.

granitoid gneiss near the Heights of Kinlochewe. As in the undisturbed areas referred to, the dykes here rise along more or less vertical fissures; they have chilled margins, and no instance was noted where a dyke had been changed into hornblende-schist. A few small dykes of ultra-basic rock (picrite) also occur here.

Apart from the resemblance in petrographical characters, the horizon of this thrust gneiss is clearly proved by the fact that it is covered unconformably by the Torridon Sandstone, and shows the double unconformity between the Cambrian strata and the Torridon and Lewisian rocks.

South of Kinlochewe a narrow belt of gneiss, in places highly deformed, occurs not far below the outcrop of the Moine thrust-plane east of Coulin, 4½ miles south of Kinlochewe, which will be referred to in Part IV. Small bosses appear in the Coulin Forest forming the cores of isoclinal folds in the basal division of the Torridon Sandstone. The surfaces of these displaced masses in the Kinlochewe region show the appearances characteristic of the weathering in pre-Torridonian time, in that they are traversed by numerous strings of epidote and are much epidotised.

CHAPTER XIII.

THE LOCH TORRIDON DISTRICT—RONA AND RAASAY*.

A. Loch Torridon.

This district is bounded on the north by the southern limit of the ground described in Chapter XII., and extends southward across Loch Torridon as far as the Lewisian rocks appear at the surface or to a line drawn from the head of Loch Gaineamhach eastwards by the head of Loch Shieldaig to the foot of Loch Damh, as shown on the map. The Lewisian rocks form around the constricted part of Loch Torridon and on the southern shore of the upper loch a series of irregularly-shaped inliers surrounded and separated by the Torridon Sandstone. A few small inliers also appear among the Torridon Sandstones in the valley that separates Liathach from Beinn Dearg, and on the western slopes of the latter mountain. Part of the pre-Torridonian topography is well displayed here. The two areas of gneiss to the east and west of Loch Shieldaig may be regarded as portions of two parallel ridges of that ancient land-surface from which the overlying sedimentary strata have been to a greater or less degree removed by denudation†. The westernmost of these ridges forms a continuous belt of varying breadth that extends in a north-east direction from Croicbheinn in the Applecross peninsula into the Shieldaig Forest on the north side of Loch Torridon—a distance of about 12 miles. Its summits on the south side of the loch reach a height of from 500 to 900 feet above sea-level. Across the Narrows the gneiss rises to 1000 feet above Loch Diabaig, and reaches the 1750 feet contour-line on the slopes of An Ruadh-Mheallan, the crest of the ridge at this point being still concealed beneath the sandstones.

The eastern ridge is represented by a series of disconnected areas that begin in the north with the inliers on Beinn Dearg. On the further side of the pre-Torridonian depression that is partly occupied by Upper Loch Torridon, the gneiss appears again on the promontory between Ob Gorm Mòr and Ob Gorm

*The portion of this chapter dealing with Loch Torridon is by Mr. Hinxman; the part descriptive of Rona and Raasay by Mr. Teall. The whole of the district is comprised in Sheets 81 and 82 of the Geological Map of Scotland on the scale of ($\frac{1}{63360}$) one inch to a mile.

†See A. Geikie, *Nature*, XXII. (1880), p. 400.

Beag, and forms a large area round the foot of Loch Damph and the Balgy River. The two ridges seem to be connected beneath the northern end of Beinn Shieldaig by the gneiss of the Shieldaig peninsula. The sandstones of Ben Shieldaig can be seen to lie in an old valley of the gneiss which rises from sea-level on either side of that hill.

The surface of the gneiss of the western ridge, especially in the Diabaig area, is extremely bare and rugged, the country having been carved into a succession of abrupt rocky hills, separated by deep ravines, and cup-shaped hollows containing small lochans. Much of the present character of the ground is no doubt due to denudation subsequent to the removal of the Torridonian strata, and many of the deeper ravines have been excavated along the lines of post-Torridonian faults. The surface of the eastern ridge is likewise peculiarly rocky and bare of superficial deposits. Only on the ground to the north-west of An Ruadh-Mheallan, in the hollows east of Meall Dearg, and about the foot of Loch Damph, is there any considerable extent of glacial drift or peaty covering.

EARLY BASIC MASSES OF THE FUNDAMENTAL COMPLEX.

Only one instance of an ultra-basic mass forming part of the original complex has been observed in the area between the Craig River and Loch Torridon. It lies between Loch na h'Uamhaig and An Ruadh-Mheallan, a mile and a half N.N.E. of Upper Diabaig. It forms a lenticular band one-third of a mile in length, the western end passing beneath the red grits of the basal Torridonian group. It measures 50 yards across its widest portion. The rock is an olivine-hornblende-peridotite. Other examples of the same type occur to the north of the Craig River.

The numerous narrow bands of foliated amphibolite and hornblende-schist, that appear at first sight to form an integral part of the gneiss in the areas where it has been affected by the secondary foliation, can for the most part be shown to have an intrusive origin. They are more fully described in the section dealing with the dykes of the district. Other foliated basic masses of more doubtful origin, however, may possibly represent basic portions of the original complex. Where the original banding has not been destroyed, the usual knots and lenticular bands of hornblende-rock appear here in more or less abundance, and it seems probable that some of the more basic bands in the reconstructed flaggy gneiss may represent these early masses in an altered condition.

GNEISS OF THE FUNDAMENTAL COMPLEX.

The original type of the gneiss is best displayed in the extreme northern part of the area between the Craig River and An Ruadh-Mheallan. It is there a massive quartzose pyroxene- or hornblende-rock in which the early banding is often very indistinct. South of Loch Airidh Eachainn narrow bands of micaceous gneiss with a north-west strike and secondary foliation begin to appear, the discordance between the older and newer foliation-planes being distinctly apparent. Towards the shore of Loch Torridon the older banding becomes almost entirely replaced by the secondary foliation, though even where the latter is most prevalent the wavy lines of the older planes can generally be detected on close examination.

This modified gneiss is typically developed along both sides of Loch Shieldaig, and on the promontory which separates that loch from Upper Loch Torridon. It belongs to Group IV. 1 of the classification detailed in Chapter IV., and consists of rocks in which biotite is the principal ferromagnesian constituent, with quartz and felspar. It presents the appearance of a flaggy, thoroughly-foliated, micaceous gneiss, often highly felspathic, and sometimes containing hornblende in addition to the biotite. A large proportion of it is highly acid, consisting chiefly of quartz and felspar, and having the appearance of a foliated pegmatite. These pegmatitic bands, that are now thoroughly incorporated and plicated with the gneiss, may represent an early acid intrusion forming part of the rocks of the original complex.

Inlier of Beinn Dearg.—The muscovite-biotite gneiss of Group V. (ante, p. 44) is typically developed in the inlier of Lewisian rocks that lies at the head of Coire Mhic Nobuil between Beinn Dearg and Liathach, about a mile and a half to the north-east of Torridon House. This inlier occupies a triangular space about half a square mile in extent on the southern slopes of Beinn Dearg, rising at its apex to a height of upwards of 1800 feet above sea-level. The unconformable junction between the gneiss and the overlying Torridon Sandstone is well seen on the west side above the 1500 feet contour-line; and a good section of the gneiss is exposed along the bed of the stream in the bottom of the valley. The intervening slope is obscured by drift and the hill-wash brought down by the mountain torrents.

The rocks of this area have been thoroughly reconstructed. They show marked parallel foliation, and in certain places are even schistose in character, their divisional planes often having a silvery lustre from the white mica developed on them. In addition to the micas, they contain microcline, oligoclase, and quartz, and show traces of cataclastic structure.

Associated with these muscovite-biotite-schists there are bands in which biotite is the predominant mineral; while others, chiefly composed of quartz and felspar, possibly represent sheared pegmatites. Bands and eyes of garnetiferous amphibolite may also be observed, some of which are markedly schistose. The origin of these basic bands is doubtful; possibly some of them may be portions of the early complex.

The strike of the gneiss in this area is generally N.N.W., the foliation-planes being vertical or dipping west at high angles.

The early banding in the original type of gneiss of the northern area has a general north-east strike, but with local variations, the rocks sometimes undulating and dipping in various directions at low angles. The foliation-planes are almost invariably crumpled and irregular in their arrangement. The reconstructed flaggy micaceous gneisses are distinguished, on the other hand, by the uniform disposition of their divisional planes. The foliation dips steadily to the north-east at angles of 40°-50°, giving a striking appearance of regularity to the rocks along the coast east of Diabaig. This regularity is heightened by the banding effect produced by the numerous narrow belts of dark basic material that are foliated with the gneiss.

DYKES.

Reference has already been made to the occurrence of numerous parallel bands of basic rock that traverse the gneiss in a south-east-north-west direction, more or less parallel to the strike of the secondary foliation of the gneiss. The thinner bands, varying from a few feet to 20 yards in breadth, are, as a rule, completely foliated throughout, and the intrusive relations of these belts of hornblende-schist to the surrounding gneiss have often been so entirely obliterated by the movement which produced the foliation, that they now appear to form an integral portion of the reconstructed gneiss. This is particularly observable in the ground to the south and east of Lagan Dubh; immediately north of Shieldaig village; on Beinn Tire, west of Loch Shieldaig; and between Kenmore and Arrin a' Chruinach, on the western margin of the most westerly tract of gneiss. Where, however, the original banding has not been destroyed, the transgression of the early lines of structure by the foliated basic bands is distinct, and their dyke-like relations to the original gneiss can be clearly established. The evidence of this discordance between the two sets of structure-lines is well seen in the area round Loch Airidh Eachainn, three-quarters of a mile N.N.E. of Loch Diabaigs Airde, on the north side of Loch Torridon.

In addition to these hornblende-schists, many other bands and masses of basic rock may be noted, whose intrusive origin in the form of dykes is plainly apparent. They consist of foliated or unfoliated amphibolites (epidiorites), distinctly coarser and less foliated in the centre than at the edges, and often so felspathic as to present a mottled appearance in the central portions, or even with distinct phenocrysts, now replaced by aggregations of secondary felspar. One of these coarse felspathic epidiorite dykes crosses the point of Rudha na-h-Airde Glaise, opposite Loch Shieldaig, where it has a breadth of more than a hundred yards. A continuation of the same dyke appears on the promontory a mile to the north-west, where the central position is unfoliated, and has a peculiar ropy or convoluted appearance, from which it derives its local name of the "Guts rock." A short distance inland this dyke suddenly contracts to a width of a few yards, changes its direction, and, cutting across the foliation-planes of the gneiss, coalesces with a parallel dyke a short distance to the east.

A group of coarse epidiorite dykes, foliated only at the margins or along certain bands, traverse the gneiss in the area between An Ruadh-Mheallan and Upper Diabaig. The boundaries are in many places irregular, with branches and apophyses penetrating the gneiss and crossing the lines of banding. One of the largest of the basic dykes in the whole district crosses the Craig River three-quarters of a mile west of Loch Gannach Beag (on the northern margin of Sheet 81), and to the south of that stream has a breadth of over 90 yards. The dyke can be followed along the slopes of An Ruadh-Mheallan, where for nearly a $\frac{1}{4}$ mile it is partially covered by the sandstones. It is then thrown 120 yards to the east by the Loch Diabaigs Airde fault, and finally disappears beneath the Torridonian rocks in the bed of the Alligin burn. The rock is a coarse epidiorite, and nowhere along its course shows any distinct parallel structure.

The numerous dykes that cross the Shieldaig promontory are more completely foliated than those just described, the narrower bands having been converted into hornblende-schist. Another basic mass of somewhat irregular outline runs north-westwards from the shore of Ob Mheallaidh. It is 500 yards in length, with a maximum breadth of 130 yards, but thins out rapidly towards its western extremity. The rock is mostly coarse and felspathic, but foliated throughout. Its intrusive origin is shown by its relations to the surrounding gneiss where the latter is in an unmoved condition.

Between Shieldaig and Camas an Leim several other dykes may be seen, 30-40 yards in breadth, consisting of foliated epidiorite, often coarse and with conspicuous felspar in their central portions. At Camas an Leim they are much dislocated by a set of parallel faults that run N.N.E.

The connection of the foliation of the basic dykes with the movements that produced the secondary north-west foliation is well shown in the area between Ob Mheallaidh and Balgy. A broad dyke of coarse epidiorite runs north-west from Balgy and traverses an area of mostly unmodified gneiss in which the early north-east banding in still prominent. Save at the extreme edges in a few places, this dyke is entirely unfoliated, while a branch of the same dyke, which crosses an area of flaggy micaceous gneiss a short distance to the south, has been completely sheared.

On the Aird Mhor, the point of land which separates Ob Gorm Mor from Ob Gorm Beag, a broad basic dyke has weathered out, forming a trench-like hollow, an unusual feature in the dykes of this district. The vertical wall on the north side of this hollow shows distinct glacial striæ, so that the weathering-out of the dyke was anterior to the last glaciation of the country.

LATER PEGMATITES.

In addition to the acid rocks resembling sheared pegmatites that are incorporated with the gneiss, many veins of pegmatite appear to which a later origin can be assigned. Some of them follow a direction parallel to the planes of foliation of the flaggy granulitic gneiss, but others distinctly transgress the foliation of the different members of the gneiss and of the hornblende-schist bands. Many of them are well-foliated, and in some cases show marked "augen-structure" with large "eyes" of microcline. Their foliation is parallel to that of the rocks in which they occur. It would therefore seem probable that this last intrusion or segregation of acid material began before the movements that produced the secondary foliation had entirely ceased, and that the pegmatites have shared in some cases in these movements.

These foliated pegmatites are well seen on the Shieldaig promontory, especially to the north and north-west of the village, where they traverse the bands of foliated basic rock. The later pegmatites are also abundant along the coast-section on the north side of Loch Shieldaig and on the Ardheslaig peninsula. On the north and west sides of the latter locality several veins of unfoliated acid rock of considerable breadth have been intruded along the foliation-planes of the gneiss.

NORMAL FAULTS.

Reference may here be made to the numerous more or less parallel normal faults which, with a prevalent north-easterly trend, traverse the Lewisian areas as well as the Torridon Sandstone of this district. The most powerful of these dislocations, which has determined the line of the valley of the Applecross River, crosses Loch Shieldaig from Inbhirban to a point immediately east of Rudha na h-Airde Glaise. That portion of its course which falls within the district now under description is of post-Torridonian age. The fault throws down the Torridon Sandstones to the east against the Lewisian rocks along the lower part of the Allt an t-Strathain, and again on the north side of Loch Torridon for a distance of nearly a mile along the burn that flows past Alligin Suas.

Another fault which crosses the district from a point on the coast half a mile south-east of Loch Diabaig to Ruadh-Mheallan is also of post-Torridonian age, and lets down small patches of the basal grit and breccia among the gneiss to the north of Loch Diabaigs Airde. This fault appears to join the Applecross-Inbhirban fault along the eastern slopes of An Ruadh-Mheallan, and the line of dislocation can be further traced through the Shieldaig Forest to Bus-Bheinn, a short distance south of Loch Maree.

The Lewisian area on the south side of outer Loch Torridon has its western margin defined by a fault which runs southwards from Arrin-a-Chruinach past Loch na Creige, and brings down the Torridon Sandstone against the gneiss which along the fault face forms a vertical cliff above the eastern shores of that loch.

B. Rona and Raasay.

The island of Rona is wholly composed of Lewisian gneiss, and presents the usual features of that formation. The elevated portions consist of bare rock alternating with peat and heather. In the low ground about the Dry Harbour and Doire na Guaile small irregular patches are cultivated by the few crofters who inhabit the island, and used for growing potatoes and oats. There is also a little pasture land on which a few cattle are reared, while trees are feebly represented by a small plantation of hazel and rowan on the north side of Big Harbour.

The only rocks capable of representation on the geological map are the fundamental gneissose complex, black bands or dykes of hornblende-schist, and two or three dolerite-dykes of Tertiary age. Pegmatite veins also occur.

The fundamental gneiss is variable in its petrographical character, but the different types are not distributed in such a way as to make it possible to represent their distribution on the geological map. The prevailing rock is a biotite-gneiss with microcline, but hornblende-gneisses are not uncommon. Small lumps of hornblende-rock are occasionally found. Where the relative ages of two masses of rock belonging to the same complex can be determined, the more basic mass is the earlier. Thus the veins are more acid and the inclusions more basic than the surrounding rocks. Definite parallel banding is by no means a well-marked feature of the gneiss as a whole, and when present is rarely found to be persistent for any considerable distance. A few arrows have been placed on the map marking the local dip of the main foliation, but these are of very little value, for in vertical sections dips in different directions may frequently be observed. There is nothing either in the structure or composition of the gneiss to suggest that any portion of it is of sedimentary origin.

The dark bands of hornblende-schist are the only portions of the Lewisian Gneiss which are capable of separate representation on the geological map. These are fairly uniform in petrographical character, offering in this respect a marked contrast to the fundamental gneiss. In the majority of cases there is no difficulty in separating them from the gneiss, but as the more basic portions of the latter sometimes resemble them, it was found difficult, in the case of one or two isolated exposures, to say to which group a particular rock belonged.

That the basic hornblende-schists or the original rocks out of which they have been formed were later in date than large portions, if not the whole of the mass which is mapped as fundamental gneiss, is proved by the occurrence of transgressive junctions. Such junctions may be observed at the margins of the two bands to the left of the path leading from the landing-stage to the Lighthouse in the extreme north of the island. But notwithstanding the clear evidence of transgressive junctions, there is on the whole a parallelism between the foliation-planes of the gneiss and the margins of the black bands. Where a north-west and south-east strike is strongly marked the foliation in the hornblende-schist is usually parallel with the junctions; in other cases, there is frequently great confusion in the arrangement of the foliation. The thicker the band the coarser is the texture, and the marginal portions often have a finer grain than the more central parts. In the northern part of the island the bands dip at a high angle, and their north-west and south-east strike is strongly marked. South of Big Harbour the dip is much less and the bands are in places horizontal, so that the hornblende-schist forms much larger portions of the surface. In this district the north-west and south-east strike is lost.

The northern part of the Island of RAASAY is mainly a repetition of the features seen on Rona. In the neighbourhood of Torran the dreary monotony of the typical Lewisian landscape is relieved by small trees and bushes of birch, hazel, and willow, but this is due in a large measure to a small isolated patch of Torridonian Sandstone which fringes the shore below the School-house and runs inland in the form of a tongue as far as Upper Arnish.

The main divisional planes of the gneiss often dip at gentle angles. There is, however, on the whole, a north-west and south-east strike, and it appears as if the layers were arranged in elliptical domes and troughs, the longer axes of which lie in this direction. Vertical or nearly vertical jointing is also strongly marked, and this gives rise to gashes, escarpments, and sometimes actually overhanging cliffs. The zones of vertical jointing often run in a north-west and south-east direction, and the separate joints are not infrequently occupied by Tertiary dykes of olivine-dolerite. The gneiss is in the main of an acid type. Biotite-gneiss is the dominant rock, but hornblende-gneiss and lumps of hornblende-rock are occasionally found.

One very common type is a medium-grained pink gneiss, which forms massive layers, and is often well exposed in cliff faces and inland escarpments. Some portions of it are rich in biotite; others are almost entirely composed of quartz and felspar. The two varieties are arranged in layers or "schlieren," and folding and puckering are extremely common. Parallel structure is, as a rule, most marked on faces running north-west and south-east, puckering and folding on those which run at right angles to this direction. The gneisses of more basic character also show a differentiation into white or nearly white quartzo-felspathic portions, and dark, sometimes black, hornblendic portions. The two varieties show banding and puckering of the same type as that seen in the pink gneisses. Pegmatites of two types occur—pink and white. The pink pegmatites, which are the most common, are associated with the pink gneisses, and merge occasionally into the quartzo-felspathic portions of these gneisses. Microcline is the dominant felspar, and individuals measuring a foot or more across may occasionally be seen.

The white pegmatites are associated with the more basic portions of the gneiss, and oligoclase is the dominant if not the only felspar present.

Bands of hornblende-schist are not so common in Raasay as in Rona. They are more uniform in character than the gneiss, but the larger masses show marked signs of differentiation. The relations of these bands to the dominant gneiss are not clear, though there is evidence to show that they are older than some at least of the pink gneisses; for they are often cut by the pink pegmatites, which, as already stated, sometimes merge into the quartzo-felspathic portions of these gneisses.

About 150 yards west of north of the summit of Beinn na h'Iolaire sill-like masses of pinkish granite clearly cut across the banding of the biotite-gneiss. It is possible, therefore, that much of the pink gneiss which is mapped as a portion of the Fundamental Complex may be of later date than the hornblende-schist and of the same age as the gneissose granites of the Laxford area.

CHAPTER XIV.

LOCH CARRON TO POINT OF SLEAT (SKYE).

A. Loch Carron to Loch Alsh.*

The district now to be described extends from Sgòrr a' Gharaidh and Glas Bheinn (two to three miles north from the village of Loch Carron) southwards across Loch Carron to the shores of Loch Alsh. It differs in one important respect from the ground to the north which has been dealt with in the foregoing chapters, for whereas the Lewisian Gneiss hitherto discussed has lain almost entirely to the westward of the post-Cambrian thrust-planes, and has not been displaced by them, the rocks now to be noticed have all been affected by these movements. As the new structures thus superinduced upon them will be described in Part IV. of this Memoir, it will be sufficient in this place merely to point out their general petrographical characters as undoubted portions of the same series of rocks which have been the subject of the previous chapters, and their distribution on the ground.

On the north side of Loch Carron the area occupied by these thrust gneisses between Achnashellach on the Highland Railway and Stromeferry amounts to about twelve square miles. Instead of being overlain by the Torridon Sandstone, as in the normal relation, the position of the rocks has here been reversed. The sandstones and basal conglomerates have been inverted, and now dip under the older crystalline masses, which rise into a lofty escarpment above them. The topography of the ground occupied by the Lewisian rocks in this area resembles that of many parts of the typical gneiss country further north.

On Glas Bheinn and Sgòrr a' Gharaidh the rocks consist of biotite and hornblende-gneisses with bands of hornblende-schist, which evidently represent the basic dykes in the unmodified areas of Lewisian Gneiss in Ross and Sutherland, already described, for many of them still show intrusive junctions. They also include a considerable development of early basic material, composed largely of garnet-amphibolite, and traversed by massive pink pegmatites, which are well seen on the hill-slope about a mile west of Slumbay and south of Sgòrr a' Gharaidh.

* By B. N. Peach and J. Horne. The district here described is comprised in Sheets 71, 81, and 82 of the Geological Survey Map of Scotland on the scale of ($\frac{1}{63360}$) one inch to a mile.

An important feature of this displaced mass is the occurrence in it of a massive sill of hornblende-schist, which with minor bands of the same material closely resembles the Ben Lair intrusive sheet north of Loch Maree. This type has been traced almost continuously from Cearcall Dubh, north-east of Loch Kishorn, south by An Sgòrr to Kyle Strome, and beyond Stromeferry to Gleannan Dorch, south of Duncraig. Along part of this line it forms a portion of the prominent escarpment of Lewisian rocks that overlie the inverted Torridon Sandstone. In certain places, as, for instance, on the hill-slope one mile W.N.W. of Strome Castle and on the north-west slope of Bad à Chreamha, these hornblende-schists are associated with flaggy garnetiferous mica-schists and rusty brown mica-schists, which appear as thin bands folded with the sill. In places they are garnetiferous, and recall certain zones of the altered sediments in Gairloch and at Loch Maree, already described in Chapter XII.

On both sides of Loch Carron all the Lewisian rocks dip to the E.S.E. in common with the underlying Torridon Sandstone strata, but northwards between Cearcall Dubh and Sgòrr a' Gharaidh the inclination varies considerably.

Both the hornblende-schists and the biotite-gneisses of the Fundamental Complex are traversed by pink pegmatites like the early basic masses, which, in places, have been much sheared by the post-Cambrian movements. The accompanying reproduction of a photograph (Plate XXIX.) illustrates the marked phacoidal structure on a large scale developed by the shearing in these pegmatites west of Stromeferry Station. A fine flaser structure has not infrequently been developed, and the felspars then form augen in a mylonised matrix.

Between Stromeferry and Glen Dorch, apart from the finely-foliated hornblende-schist already referred to, the rocks consist of biotite gneiss resembling in part the Meall Riabhach type north of Loch Maree, their general dip being to the E.S.E. or south-east. Beyond Glen Dorch towards Loch Alsh, the Lewisian rocks are highly sheared and merge into platy mylonites, the relations of which will be described in Part IV.

B. Skye.*

In Skye also the Lewisian rocks are not in their normal position and condition, but, like those of Loch Carron and Loch Alsh, of which they are a continuation, have been largely modified in structure. They are confined to the peninsula of Sleat, where they appear in a number of detached areas according to the position of the great thrust-planes by which they have been displaced. The most easterly of these lines of movement or Moine thrust-plane is followed by some others further west, and

* By C. T. Clough. The district here described is shown in Sheets 61 and 71 of the Geological Survey Map of Scotland on a scale of ($\frac{1}{63360}$) one inch to a mile.

the Lewisian rocks are found partly on the Moine thrust and partly on those below it. They are never covered unconformably by rocks which can be confidently claimed as Torridonian, but are frequently folded with altered sediments like those of the "Moine series" of Sutherland and Ross. The junctions of the two groups of rocks, however, show no clear evidence of unconformability, or of the intrusion of the one group into the other.

The most northerly exposure of Lewisian rocks appears in Dun Ruaige, a mile south of Kylerhea, and is only 250 yards long. The rocks are there all in a mylonised condition, and are probably separated from the Torridonian rocks on the east side by a thrust. The other areas of them lie to the south-west of Loch na Dal, one and a half miles north of Isle Ornsay. Of these much the largest area strikes from Camas a' Mhuilt to Aird, near the Point of Sleat, a distance of about 11 miles, and reaches a breadth of nearly two miles and a half. Here the rocks lie upon the Moine thrust. Most of the surface of this area is smooth, showing few rock-exposures save on the coast and between Knock Bay and Isle Ornsay. The material of some of these rocks is in many places so soft that it can be scooped out with the hand. From their general tendency to decomposition, the Skye gneisses have given rise to a much smoother form of surface than is found in the undisturbed gneiss tracts of the west of Sutherland and Ross.

The gneiss below or to the north-west of the Moine thrust lies on the Tarskavaig, Caradal, and Lamarscaig thrusts. It is greatly mylonised, and the boundary between it and the adjacent Moine rocks is sometimes a little uncertain. The most extensive tract occurs on the Lamarscaig thrust, and is about two miles long and three-quarters of a mile broad at the maximum. On the west side the boundary with the Moine rocks is repeatedly folded and shows no evidence of thrusting. Near the west limb of the Caradal thrust small exposures of rock appear in several places, while a larger exposure extends from three-quarters of a mile E.N.E. of Rudh' an Iasgaich to 200 yards of Geur Rudha.

The gneiss on the Tarskavaig (south of Loch Eishort) thrust makes an almost continuous, but usually narrow, strip along the outcrop of the thrust. On the coast between Gillean and about 1500 yards south-west of Gillean it is sometimes only a few inches in breadth. The best sections occur on the coast two-thirds of a mile E.N.E. of the foot of Loch Nighean Fhionnlaidh (one mile south of Tarskavaig Bay) and on the hillside between Gillean Burn and the foot of Loch a' Ghlinne. At the former place the breadth of outcrop is about 150 yards, and in the latter it varies from 30 yards to nearly a quarter of a mile.

The gneiss on the south-east side of the Moine thrust includes two classes of rocks, one later than and intrusive in the other. But the later rocks, in consequence of the folding and deformation which they have suffered, are not readily separable from the earlier.

Nearly a quarter of a mile north-east from the west end of Ard

Thurinish, near the Aird of Sleat, a small exposure of calcareous chloritic schist appears, partly folded with and partly faulted against "Moine rocks." It contains two lenticles of impure marble four or five feet thick. On the coast 700 yards north-east from Ard Thurinish some calcareous bands about six inches thick can be seen.

The axial planes of the folds in the Lewisian Gneiss of Skye usually strike north-east and dip to south-east at gentle angles, but sometimes they strike north-west.

Although the Lewisian rocks of Skye have been so affected by post-Cambrian movements as to have lost most of their original characters and might therefore be most appropriately dealt with in Part IV., where the effects of these movements will be more particularly considered, an account of them by way of illustration may perhaps be appropriately inserted as the concluding portion of this chapter, which ends the detailed description of the undisturbed or normal type of these rocks.

In the following description attention will first be drawn to those representatives of the Lewisian rocks which lie to the north-west of, and therefore under, the great Moine thrust and next to those that come above it.

At the Dun Ruaige exposure (one mile south of Kylerhea) most of the mylonised rock is flaggy, of a greenish-grey colour, and with lustrous foliation planes which generally dip E.S.E., and are crossed by stretching lines running in the same direction. The stretching is here much more pronounced than in the adjacent Torridonian rocks. That the bulk of the mylonised rocks further south have been formed from the Lewisian Gneiss is probable, partly from their similarity to rocks which in other districts are known to be sheared forms of this gneiss, and partly from the character of occasional less-sheared patches. Nowhere, however, can the original relations of the different parts of the mylonised rock be ascertained, and the rocks of the early complex and of later intrusions, if, as usual, these originally existed here, cannot be separated.

One of the commonest rocks is soft, flaggy, and of a yellowish-green colour, with occasional red felspathic spots and streaks. It is well represented near Gillean and Tarskavaig. Elsewhere the red parts are more conspicuous and mixed with the greener ones in thin parallel bands, from a quarter to a few inches thick, as may be seen on the hillside half a mile N.N.E. and two-thirds of a mile east of the outlet of Loch Sgùrr na Caorach (about three miles S.S.E. of Tarskavaig Bay). The green bands occasionally contain pieces of hornblende, rarely exceeding a pea in size, or of hornblende-schist, as in the area east and north-east from Loch Sgùrr na Caorach, where some of the pieces are as much as three feet long. Their occurrence, and the frequent contrasts of red and green colours—colours which are rare in the "Moine rocks"—indicate a probable derivation from Lewisian Gneiss.

About 1000 yards N.N.E. of the outlet of Loch Sgùrr na Caorach, and for three-quarters of a mile still further to the north-east, the commonest rock, which weathers with a dirty-white colour, but has a greenish-grey fracture, consists of thin parallel streaks and lenticles of quartz, mixed with others of a honey-yellow or yellowish-green colour. A thin slice taken from a specimen (7333) obtained rather more than half a mile N.N.E. of Loch Lamarscaig outlet, shows the yellow bands to be composed of small epidote granules, with rounded outlines, and to be repeatedly crossed, almost at right angles, by thin quartz-veins which never extend far outside them. If the epidotic layers have been formed from felspathic layers there must have been a shrinkage of volume*, and the little quartz-veins have perhaps been formed along contraction cracks.

In Gillean Burn, a little more than two-thirds of a mile E.S.E. of Gillean, a dark-grey schist, with silvery white unctuous surfaces, encloses more massive eye-like portions, as much as a foot broad, chiefly composed of small grains of a yellowish-green pyroxene (7336).

The planes of the mylonised rocks are repeatedly folded and contorted, but perhaps most markedly so east from Loch Sgùrr na Caorach. A little more than half a mile slightly north of east of the loch the axial planes of the folds are occasionally waved, now dipping east and now west. Near many of the basaltic and other dykes the surface of the laminæ become less lustrous, and those which are green become dark-grey, and are difficult to distinguish from the altered phyllites of the "Moine series," or from Torridonian shales.

The gneiss which lies above the Moine thrust is chiefly granulitic, and, excepting at a few places chiefly near the thrust, it has not a mylonised aspect. The granules of the water-clear minerals are often larger than those in the mylonised rocks to the north-west; many of the flakes of mica and chlorite are also larger. In this gneiss many bands may be observed which closely resemble types of Lewisian gneiss in other unthrust areas. The commonest type of rock is fissile and granulitic, its colour varying, with the amount of chlorite, from dark-green to pale-yellowish-grey. The green colour sometimes prevails in bands half an inch thick, but is usually subordinate to the other. The surfaces of the foliation planes are lustrous, with small flakes of mica or chlorite, and occasionally with larger flakes which have their longer axes parallel. In Knock Bay (three miles S.S.W. of Isle Ornsay) the longer axes strike nearly east and west, but half a mile S.S.W. of Cnoc Malagan they strike north-west. The pale-grey parts contain parallel, thin, nearly transparent streaks which consist chiefly of quartz, while the rest of the rock contains much felspar. Needles of black actinolite, often half an inch long and crossing the foliation, are extremely abundant at some places.

This type, mixed with more gneissose pink or pale-grey rocks and occasional bands of hornblende-schist, forms the greatest

* See F. Becke, "Ueber Beziehungen zwischen Dynamometamorphose und Molecularvolumen," *Neues Jahrbuch*, Band II., p. 182, 1896.

part of the area east of the road between Isle Ornsay and Armadale. As it disintegrates with great rapidity, it has presumably given rise to the smooth features so characteristic of most of the Skye gneiss.

Near a line drawn between Isle Ornsay and Knock the flaggy soft rocks give place south-eastwards to more gneissose, less finely granulitic types. In Knock Bay, near the mouth of Allt Gleann Horavaig, the change between the two types is somewhat sudden. East of the burn acid and basic bands alternate, the former being hard and containing subparallel broad streaks of quartz, which are not always properly granulitic, together with many needles of black actinolite and large flakes of black mica and chlorite, which repeatedly cross the banding. Other areas furnish evidence that similar actinolites have been developed after the rocks were sharply folded. For instance, a quarter of a mile south-west from Sgeir Ramasgaig, the early banding is crossed by a second foliation parallel to the axial planes of fold, and most of the actinolites have been developed along the second foliation.

Bands of hornblende-schist are abundant. Some that are irregular in character and mixed with white streaks and opalescent quartz strings are probably parts of the original complex. Examples of them may be seen on the sides of Ob Snusaich and in the south-eastern and central parts of Ard Ghunel, south of Isle Ornsay. They are accompanied by smaller lenticular masses which are swathed round by laminæ of acid gneiss.

South-west from Armadale the rocks are granulitic and flaggy, and generally show thin alternating red and green bands. Extensive exposures of shivery chloritic schist appear in many places, but hornblende is rare. Here and there, not far above the Moine thrust—for instance, in Allt Bealach na Coise, about 300 yards above the road, and on the south side of Allt Duisdale, about 1000 yards above the road—the gneiss appears partially mylonised, and contains small eyes of felspar about the size of mustard seeds. Still nearer the thrust, and nearly parallel to it, occasional lines of crush break up the earlier structures of the rock. They can be seen most distinctly on the south side of Allt Duisdale between a half and three-quarters of a mile above the bridge.

Between Knock and Camas Croise a band of rather hard impure serpentine which weathers into an orange or buff colour strikes north-east, and can be traced more than a mile. It is seen best on the west side of Loch Baravaig, where it forms three hillocks*. Its greatest width is about 60 yards. While in most places it is massive, foliated varieties of it also occur. It contains abundant spots, about the size of peas, of ferriferous carbonate, and also strings of this mineral mixed with magnetite. In some places the strings of magnetite are six inches thick.

* On the top of one of these there is a Dun, not marked in the Ordnance Maps.

Magnetite also forms thin laminæ running with the foliation, as well as scattered grains and clots in the rock mass. No good junction-sections are visible, but the relation of the serpentine to a folded band of hornblende-schist on its north-western side warrants the conclusion that the former rock is intrusive.

The hornblende-schist on which Isle Ornsay lighthouse stands is in places very coarse in texture and contains hornblende crystals two inches long, also abundant garnets, which are sometimes as large as beans and united in bands an inch or two thick. It strikes E.N.E. Fifty yards north-east from the lighthouse the bands of acid gneiss with basic knots, a few feet away from the schist, strike against it at a considerable angle, but as they approach it they twist into parallelism with it and become thinner, in the way so often seen near the basic dykes of the Scourie district. On the headland 700 yards south-east of Camas Croise Pier, south of Isle Ornsay, a folded hornblende-schist of rather uniform character shows on its north-eastern side a somewhat similar junction with an acid gneiss containing basic knots. Some of the hornblende-schists on the coast to the south-east of Camas a' Mhuilt transgress the gneiss to a small extent. That the transgression is not more marked may be due to the way in which the rocks were dragged at the time they were folded into isoclines with limbs hading south-east.

Perhaps the thickest pegmatites are some unfoliated veins in a hornblende-schist at the top of a scar 300 yards north-east of Loch nan Dubhrachan, about two miles south-west of Isle Ornsay. The hornblende-schist at Isle Ornsay lighthouse contains red pegmatites a foot or two thick and without foliation.

PART II.

TORRIDONIAN.

CHAPTER XV.

DISTRIBUTION AND GENERAL CHARACTERISTICS.*

Area and Scenery.—The rocks included in the Torridonian series present a striking contrast to those of the Lewisian gneiss, inasmuch as they consist mainly of red sandstones and conglomerates which over much of their extent are gently inclined or horizontal. They stretch in a N.N.E.-S.S.W. direction along the western sides of the counties of Sutherland and Ross, forming a more or less broken belt that runs for 115 miles from Cape Wrath to the Point of Sleat in Skye, and attain a maximum breadth, measured between Gairloch and Strathcarron, of about 20 miles. In the extreme north of Sutherland they occupy the greater part of the wild region lying between Cape Wrath and Loch Inchard. Further south they occur in disconnected patches, forming the island of Handa, the flat promontory of the Rhu Stoer, and the strange isolated peaks of Quinag, Canisp, and Suilven that rise on either side of Loch Assynt. Across the northern boundary of Ross-shire they are more extensively developed, since they cover the whole of the Coigach district and the promontory between the two Lochs Broom, whence they stretch southwards in a gradually diminishing belt to the head of Loch Maree, where they rise into the imposing mass of Slioch; while another large isolated area in the west forms the Rudha Mòr and the low ground on either side of Loch Ewe.

But it is in the districts of Gairloch, Torridon, and Applecross that this formation reaches its maximum development, for it extends in almost unbroken continuity for twenty miles eastwards from the shores of the Applecross peninsula into Strathcarron. Nowhere are its sandstones more characteristically developed than in the mountainous country that surrounds the head of Upper Loch Torridon, a region which suggested the appropriate name of Torridon Sandstone, first applied to these rocks by Professor Nicol. The Applecross mountains, with their colossal escarpments and huge precipitous corries, likewise display on the grandest scale the characteristic scenery of these rocks. (See Plate III.)

* By L. W. Hinxman, with notes by B. N. Peach and E. Greenly.

The most southerly extension of recognisable Torridonian strata detected up to this time on the mainland occupies the promontory between Loch Carron and Loch Alsh, and forms a narrow stripe along the eastern shore of the Kyle Rhea. Across the Kyle they pass into the Island of Skye, and are continued southwards through the peninsula of Sleat. That they once covered a far wider space than that to which they are now restricted is shown by the distribution of small outlying areas of these rocks among the Western Isles. They form the central portion of Raasay, the greater part of Scalpay, the Crowlin Islands, Soay, and the northern half of Rum.

The greater part of the ground covered by the Torridonian series is essentially a mountain region. The most striking features of the scenery of the North-West Highlands are due to the long line of red sandstone mountains that flank the western seaboard of Sutherland and Ross. At the northern end, though the Torridonian belt begins with the comparatively low hills of the Parph, it plunges into the Atlantic in a magnificent range of mural cliffs along the northern coast near Cape Wrath. Further south it reaches heights of 2400-2700 feet in the Assynt and Coigach districts, and culminates south of Loch Broom in the shapely cones of An Teallach in Dundonnell (3483 feet) and Liathach, at the head of Loch Torridon (3456 feet).

Most of these hills have a unique personality that at once distinguishes them from the ordinary mountain-forms found among the metamorphic rocks of the Highlands. They rarely coalesce into a continuous range, but rather tend to stand out in more or less detached masses isolated from their fellows. This isolation is most complete in the mountains of Assynt, where the greater part of the sandstone formation has been removed by denudation, leaving such solitary monolithic forms as the well-known and often-described peaks of Quinag, Canisp, and Suilven*. (Plate I.) The successive stages in the process of sculpture may be impressively traced from south to north along the Torridonian belt. Almost the first stage may be seen where a portion of a high-level table-land is, as it were, just beginning to be detached as a separate mountain, such as Bheinn Bhàn of Applecross. A further step is reached in such a mountain as Liathach, separated on every side by deep glens from its neighbours, but still forming part of a closely-serried group of similar masses. This individualisation becomes more and more marked towards the north until we reach completely isolated ridges and pyramids of sandstone standing alone on the bare platform of gneiss, as in the long, narrow, wall-like mass of Suilven, with its crest deeply cleft into successive peaks by gullies that have been

*The peculiar scenery of the Torridon Sandstone mountains has been referred to by various writers, particularly by Macculloch—*Geology of the Western Isles*, vol. ii., p. 90 *et seq.*; Macculloch—*Letters to Sir Walter Scott*, vol. ii., p. 344 *et seq.*; and by Hugh Miller—*The Old Red Sandstone*, 22nd edit. (1879), p. 53; *ibid.*, *On the Red Sandstone, Marble, and Quartz Deposits of Assynt*, p. 328 *et seq.* It is more fully described in Sir Archibald Geikie's *Scenery of Scotland*, 3rd edit., pp. 80, 127, 222, 246, 505, 508.

carved out along vertical joints or lines of fault. But the process of decay still continues, and various stages in the degradation and demolition of the isolated sandstone cones and pyramids can be followed, as in the shattered knife-edge of Stack Polly, which has been splintered into fantastic pinnacles, and is now obviously wasting down to the general level of the surrounding country. It is thus manifest that these mountains remain as only the scattered fragments of a great formation which must once have risen much higher and extended much further than it does now.

The denuding forces, acting on a series of rocks very homogeneous in composition and arranged in gently-inclined or horizontal strata, tend to produce outlines at once simple and massive and more or less architectural in form. Hence the characteristic features of these sandstone mountains appear in regular cones, rounded bastions and buttresses, and flat-topped mural precipices, while the parallel lines of bedding which may be traced from base to summit of the cliffs look like piles of Cyclopean masonry. Where the strata are horizontal or nearly so, and are traversed by strong vertical joints or faults, the mountains assume on every side more or less precipitous shapes and rise abruptly in terraced escarpments or round castellated piles of flat cake-like masses, separated from each other and trenched by deep *couloirs* or rock-chimneys.

Along the landward side of the area, where the dip is usually regular and inclined gently towards the east, the escarpments look westward and north-westward to the sea, while the slopes follow the general direction of the dip. The latter, however, are rarely for any distance dip-slopes, the general angle of the hillsides being, as a rule, greater than the inclination of the strata. The smooth regular profile as seen from a distance seems often to be that on which the covering of Cambrian quartzite that has recently been stripped off them was laid down. A closer examination of these slopes shows also that their smoothness is more apparent than real, seeing that they consist of a series of alternating dip-slopes and basset edges, which give rise to the successive low terraces that follow one another in parallel lines along the hillsides, and form one of the most characteristic features of Torridonian scenery. On the high ground these terraces are usually bare and strewn with boulders, but lower down they become masked under a covering of thin peaty soil and rough herbage that gradually soften down their outlines into a uniform slope.

Reference has already been made to the deeply-incised features produced on the mountain sides by the vertical joints. These joints also play an important part in determining the course of the streams. When, in the lower part of their course, streams strike a joint, they often follow its trend as a line of least resistance for a considerable distance. They have thus been enabled to erode deep and narrow chasms with perpendicular sides which may run for half a mile or more in an absolutely straight line. These miniature *cañons* are also a marked feature of the eastern schists, where those rocks most closely resemble the Torridon Sandstone in its modified form. Besides these stream-gorges, the lines of fracture have given rise to dry gullies —locally known as "clashes"—which can often be traced for long distances, and even across existing watersheds. Similar features are also produced by the weathering-out of the less-resisting igneous material of intrusive dykes. Much of the characteristic coast-scenery of the north and west of Sutherland and Ross is due to the way in which the Torridonian rocks yield to the forces of marine and subaerial denudation. The horizontal and evenly-bedded strata, cut by vertical joints, rise in long lines of mural cliff, which by the action of the waves along these joints are hollowed out into caves and deep chasms known as "gloups" or "gyoes." These characteristic features are strikingly displayed on the range of sandstone precipices to the east of Cape Wrath*.

An increase in the general angle of dip produces a corresponding change in the scenery of the Torridonian rocks. Where the inclination of the beds exceeds that of the hill-slopes it gives rise to a series of parallel rib-shaped features, determined by the outcrops of successive beds of sandstone, with intervening hollows. The type of scenery thus produced is much more rugged and irregular than that which prevails in the normal denuded plateau area.

The various aspects of the Torridonian landscape here described are all subject to the well-known modifications due to glacial action. These modifications are naturally most apparent on the lower hill-slopes and in the valleys, where the *roches moutonnées* and the wonderfully fresh appearance of the polished and grooved surfaces of bare sandstone cannot fail to strike the most casual observer.

Lithology and Stratigraphy.—The prevalent lithological and stratigraphical features of the Torridonian series are the uniformity of composition and fresh appearance of the rocks, and the regularity and generally undisturbed character of their disposition. Indeed, the observer who studies these rocks in the unmoved area west of the great line of dislocation finds it difficult to realise that such unaltered sediments, which he sees resting almost in the position in which they were originally laid down, are the oldest recognisable sedimentary deposits in the British Isles.

The great bulk of the formation consists of more or less coarse-grained arenaceous sediments in the form of felspathic grits and sandstones (arkose), with occasional thin intercalations of fine-grained micaceous shale and sandstone. Coarse angular breccia occurs as a local base, and numerous bands of pebbly grit, conglomerate, and scattered pebbles are found at different horizons, while the whole series is characterised by false bedding and other signs of current action. A slight decrease in the coarseness of the material is perceptible towards the southern limits of the area, accompanied by a corresponding increase in the number

* *Scenery of Scotland*, p. 80.

and thickness of the finer bands intercalated with the arkose. In the central portion of the belt, where they are best developed, the arkoses reach a thickness of 6000 feet, pointing to a long-continued uniformity in the conditions of deposit.

From the nature of the rocks it may be inferred that the conditions of deposit were probably those of a rapid accumulation in shallow water near a shore line, subject to violent currents and the influx of flood or stream-borne materials, with occasional intervals of quiescence during which the finer sediments were laid down; while the permanence of these conditions may be accounted for by a long-continued subsidence, taking place contemporaneously and at the same rate with the deposition of the sediments. The remarkable freshness of the felspars in the arkose points to a disintegration of the rocks, carried on at a more rapid rate than the decomposition due to chemical action. It would also seem to indicate cold climatic conditions accompanied by periodic floods of great intensity.

Both at the top and bottom of the formation the rocks are finer-grained and more argillaceous in character, and include a considerable thickness of shales and flagstones with calcareous bands. As perhaps a great part of the highest visible group of the Torridonian series had been removed by denudation previous to the deposition of the overlying Cambrian strata, the argillaceous and calcareous portions of the whole may originally have borne a much larger proportion to the grits and sandstones which make up by far the greater part of what is now left of the formation. The rain-pitted and sun-cracked surfaces of the shales and mudstones seen on Loch Torridon and elsewhere show that the fine sediments of the lowest group are shore deposits, and cannot be regarded as due to deeper-water conditions.

The base of the Torridonian series is usually formed of a conglomerate or breccia, sometimes exceedingly coarse in texture, and derived from the Lewisian rocks in the immediate vicinity. In one instance, on the north side of Loch Maree, it has been observed that the blocks in the conglomerate have come from the hornblende-schist ridge of Ben Lair, and may have travelled a distance of three miles. The conglomeratic base appears to be a local deposit not confined to any one definite stratigraphical horizon, but appearing on successive levels for two or three thousand feet upward from the base of the whole series, according to the extremely accentuated surface of the subsiding region of gneiss on which the Torridonian formation was laid down.

Leaving out of account, however, these coarse basal deposits, an examination of the materials of the Torridonian series leads to the conclusion that they have in great part been derived from rocks not now visible in the region. The epidotic grits and other members of the lowest zone contain material such as oligoclase felspar, that, like the breccias, may have been derived from local sources. But a microscopical examination of the sandstones, which make up the main mass of the series, shows that microcline, in a wonderfully fresh condition, forms an abundant constituent of and is the dominant felspar in these rocks. Our knowledge of the lithological characters of the gneiss as developed in the North-West Highlands establishes the fact that over the greater part of the area microcline does not predominate, and only occurs in any abundance in the district between Cape Wrath and Loch Laxford, where granitic gneisses and pegmatites are largely developed. Except in the local basal breccias, pebbles or even recognisable fragments of Lewisian Gneiss are rarely met with. Hence we may conclude that, while the existence of a further extension of rocks of the Cape Wrath type to the north may have to some extent supplied this characteristic constituent of the Torridon Sandstones, it cannot have been derived from the bulk of the Lewisian Gneiss as we now know it on the mainland.

The pebbles that occur so abundantly throughout the arkose series afford, however, the strongest proof of the foreign origin of most of the Torridonian sediments. As a detailed description of the pebbles from various localities will be found in Chapter XVI., it may be sufficient to state here that they include examples of sedimentary, metamorphic, and igneous rocks which are not found within the Lewisian area, and suggest the existence of a pre-Torridonian sedimentary and eruptive series as the source of the coarser materials of the Torridonian formation.

TABULAR LIST OF THE GROUPS OF THE TORRIDON SANDSTONE.

Names of Groups.	Approximate Thickness in Feet.	Nature of Materials.	Localities where Typically Developed.
3. Aultbea Group	3000 to 4500.	Sandstones, flags, dark and black shales and calcareous bands passing down into chocolate and red sandstones, and grey micaceous flags with partings of grey and green shale.	Cailleach Head; Loch Broom; Coigach; Aultbea; Applecross; Crowlin Islands; Coulin and Achnashellach Forests.
2. Applecross Group	6000 to 8000.	Chocolate and red arkoses with pebbles of quartzite, quartz-schist, felsite, jasper, etc. Occasional chocolate and red shales.	Durness; Assynt; Stoer; Coigach; Ullapool; Gairloch; Dundonnell; Torridon; Applecross; Loch Carron and Loch Alsh; Skye.
1. Diabaig Group	500 in Gairloch. 7200 in parts of Skye.	Hard, fine red sandstones at top, mixed with red mudstones and dark grey sandy shales with calcareous lenticles. At base, conglomerates made out of Lewisian gneiss. In Skye grey and buff arkoses are developed in great thickness, and the group has been divided into four zones.	Stoer; Dundonnell; Gairloch; Loch Maree; Diabaig and Loch Torridon; Loch Carron and Loch Alsh; Skye.

The Torridonian Land-surface.—The surface of Lewisian Gneiss on which the Torridonian series was laid down probably to a considerable extent resembled that of the existing surface of the older rock. It appears to have in great part presented the appearance of an undulating plateau, moulded into hollows and eminences more or less uniform in height, such as now meets the eye in the neighbourhood of Scourie or Gairloch. But the detailed investigation of the ground further to the south and east has revealed the existence of a much more diversified topography that has been exposed by the denudation of the sandstones under which it was buried. The gneiss is there found to have been carved into mountains and valleys, and testifies by the extreme irregularity of its contours that it underwent prolonged erosion as a terrestrial surface. The present lines of drainage still follow some of these old Torridonian river-valleys, while here and there an isolated peak or range of hills, preserved from the waste of time by the enveloping Torridonian sediments, remains as a fragment of the Archæan land.*

Detailed descriptions of the varieties of the Torridonian topography will be found in the successive chapters devoted to the districts in which these varieties are displayed. Only a brief reference to the more striking features need be given here.

Between Loch Inchard and Loch Carn Bhan the general surface of the gneiss has by subsequent denudation been cut below that of the ancient plateau, the only remains of which are seen on Ben Dreavie, where it has been preserved by a small capping of Torridonian conglomerate. Further south a good example of a pre-Torridonian hill rises from beneath the north-west peak of Quinag. (Plate XXXI.) Here the successive beds of sandstone abut against the steep sides of an ancient hill of gneiss that must have reached a height of 1200 feet above the average level of the surrounding country, and may well have been considerably higher.†

In the Stoer peninsula the presence of 2000 feet of Torridonian strata lower than any found on Quinag shows that in Torridonian time the difference of level in the surface of the gneiss at these two points, ten miles apart, must at least have equalled the thickness of these lower strata. It should be pointed out, however, that this estimate of the fall in the ground between Quinag and Stoer depends in a great degree upon the correlation of the rocks at the latter locality with those of the Diabaig group, and does not rest upon such direct evidence as that for the Quinag hill referred to in the preceding paragraph, and for the still more remarkable topography to be seen further south.

Further evidence of a considerable slope to westwards is found in the area between Loch Assynt and Loch Owskeich in Coigach.

* The existence and antiquity of this land-surface were noticed by Sir A. Geikie in his paper on "A Fragment of Primeval Europe," *Nature*, xxii. (1880), p. 400.

† A sketch of this Torridonian hill with its capping of sandstone is given in *Scenery of Scotland*, p. 126.

Not a few of the larger valleys in this district can be shown to have been hollows in Torridonian times, as in the case of the two higher branches of the valley of the Kirkaig, above the Fionn Loch; of the hollow on the north side of Suilven; and of the deep glen under Cul Mor at the head of Loch Skinaskink. The region of which this loch is the centre is at present one of considerable irregularity of surface, and from the present relations of the sedimentary strata to the gneiss this irregularity was obviously still more marked in Torridonian times.

The small inliers of gneiss seen in the area to the north of Upper Loch Torridon point to the existence of a range of hills of considerable height concealed beneath the sandstones of Liathach and Beinn Dearg. The gneiss rises steeply from the glen between these two mountains, and at the point where it passes beneath the sandstone on the south face of Beinn Dearg it reaches a height of 1800 feet above sea-level and more than 1100 feet above the lowest place where it is seen in the Amhainn Mhic Nobuill. The distance between these points is less than half a mile, and the angle of the hill-slope about 20°. That the surface of the gneiss continues to fall steeply southwards to a point below sea-level is shown by the appearance of the Torridonian strata along the shore on the south side of Liathach, a mile and a half from the boundary of the gneiss inlier.

The ridge of Lewisian Gneiss which crosses Loch Torridon at the Narrows and forms the promontory of Shieldaig may be regarded as another parallel range of ancient hills. That portion of it which rises immediately above the north side of the loch may owe its extremely rugged character to subsequent denudation, but further north there is evidence of the comparatively recent removal of the basal Torridonian strata that still rest up to 1000 feet on the slopes and in the hollows between hills that reach a height of 1750 feet above the sea. On the other side of Loch Torridon, where, as already stated, the ridge passes beneath the north end of Beinn Shieldaig, the gneiss rises from sea-level on either side of a deep narrow valley filled with Torridonian rocks, and is overlapped by the sandstones at the 800-feet contour on each side of the mountain.

In the area between Loch na Sheallag and Loch Maree, and again on the south side of the latter loch, six or seven distinct hills of Archæan gneiss, some of them of considerable size, can be demonstrated by the disposition of the sediments around them to be of older date than the Torridonian series. Perhaps the most remarkable of these are the hills which underlie Beinn Dearg Mhor and Beinn Dearg Bheag. The gneiss rises from the shores of Loch na Sheallag towards each of these mountains, and reaches its highest elevation—2300 feet above sea-level—immediately under the south end of Beinn Dearg Bheag. The great hollow to the north of that mountain is also of older date than the Torridonian strata.

The hollow of Gleann na Muich, south of Beinn Dearg Mhor, coincides with the edge of an ancient valley, now filled with the sandstones of Beinn Tarsuinn, Sgùrr Bàn, and Beinn a' Chlaidheimh. Two tributary glens of the same antiquity can also be traced coming in from the west and joining this valley opposite Sgùrr Bàn. The small patch of Torridonian sediment on the summit of A' Mhaigdean conceals a hollow that probably represents the head of one of these glens. Another well-marked eminence belonging to the same old topography rises from beneath the grits of Beinn Tarsuinn on the north side of Loch Fada. The deep hollow of Glen Tulacha and the great cliff of Ben Lair also date back to the same remote period, as is proved by the patch of horizontally-bedded breccia and sandstone which rests on the face of the cliff.

A still more conspicuous example of the irregularity of the ancient land surface is found on the flanks of Slioch, which rises above the northern shore of Loch Maree. This great mountain can be shown to partially envelope three distinct hills and to fill up two valleys of pre-Torridonian age. Over 2000 feet of Meall Each, the most easterly of these elevations, are still visible, and the disposition of the surrounding strata shows that it may well have reached 3000 feet. The original sides of this hill were very steep, for their scree-slopes, now compacted into Torridonian breccia, are still distinctly visible. Meall Riabhach, the central hill, forms a conspicuous feature as seen from the further side of the loch owing to the contrast of the light-gray gneiss of which it consists with the dark-purple sandstones that abut against its sides. (Fig. 11.)

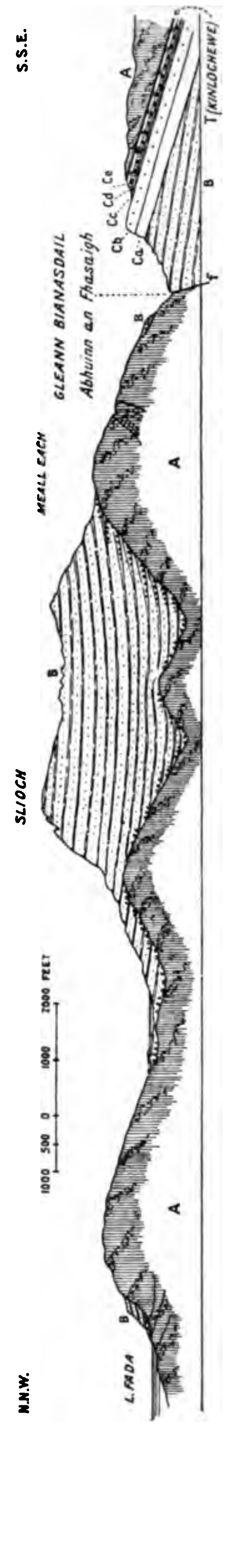


FIG. 11.—Section from Loch Fada across Slioch to Gleann Bianasdail.

A. Lewisian Gneiss.
B. Torridon Sandstone.
Ca. Basal quartzite.
Cb. Pipe-rock.
Cc. Fucoid-beds.
Cd. Serpulite grit.
Ce. Dolomite.
T. Kinlochewe thrust-plane.
f. Fault.

CHAPTER XVI.

THE PETROGRAPHY OF THE TORRIDONIAN FORMATION.*

The Torridonian rocks in the area under consideration consist of breccias, conglomerates, grits, felspathic sandstones, micaceous sandstones, and shales or slates. A few inconspicuous bands of calcareous grit occur near the base of the series in one or two localities, but limestones are conspicuous by their absence. The Torridonian formation is one of the largest as well as one of the most ancient masses of mechanical sediment in the British Isles.

In the northern portion of the area in question, and in the district from which the formation takes its name, the prevailing rock is a red felspathic sandstone or arkose, in which pebbles of rocks unrepresented in the Lewisian gneiss frequently occur. In the southern part of the area finer-grained deposits of a grey or greenish-grey colour constitute a large part of the whole series. In districts where the Torridonian rocks have been affected by the post-Cambrian movements important modifications in structure, and to a certain extent also in mineralogical composition, have been produced.

The constituents may be classified as follows:—

(1) Fragments and pebbles of older rocks derived partly from the Lewisian Gneiss and partly from formations as yet unknown in the North-West of Scotland;
(2) Mineral constituents derived from older rocks;
(3) Minerals developed *in situ*.

In disturbed regions the forms of the original clastic constituents, whether rocks or minerals, have often been considerably modified. The allothigenic constituents may therefore be divided into two classes: (1) those which have retained the form in which they were deposited (allothimorphic), and (2) those in which that form has been modified by earth-stresses (authimorphic). †

Fragments and Pebbles from Older Rocks.—Where the coarse-grained Torridon Sandstone rests on the uneven surface of Lewisian Gneiss, after the fashion of all great continental formations, it frequently contains angular blocks, of all sizes,

* By J. J. H. Teall.

† Milch, "Beiträge sur Lehre von der Regional-metamorphose." *Neues Jahrb. Beilage*, Band ix. (1894), p. 101.

derived from the immediately underlying rock. A detailed petrographical description of the contents of these basal breccias is unnecessary, as it would involve a repetition of what has been said in describing the Lewisian Gneiss. On passing upwards from these breccias into the main mass of the Torridon Sandstone, the fragments of local rocks are seen to disappear, and pebbles which cannot be matched in the underlying formation are met with. These pebbles merit a closer attention, as some of them have been derived from sedimentary formations of older date than the Torridon Sandstone, which is itself of pre-Cambrian age.

A miscellaneous collection of pebbles made by Dr. Horne north of Strath Lingard, E.N.E. of Loch Maree, yielded on examination the following result:—

Vein quartz - - -	50	per cent.
Quartzite - - -	20	,,
Chert and jasper - -	16	,,
Grit - - - -	8	,,
Felsite and felspar-porphyry	6	,,
	100	

The vast majority of the true pebbles belong to the types above referred to, but a few exceptional varieties may be occasionally recognised. No special importance must be attached to the figures given above. The relative proportions of the different varieties vary from place to place, as will be seen by referring to the results obtained by Mr. Clough (page 333).

The pebbles of vein-quartz are so uniform in character that only one section has been prepared. The pebble, which is from the Applecross district, is white with reddish staining along cracks. It is composed of large irregular grains of quartz which interlock with each other along sutural junctions. The rock is in every way identical with that which occurs so commonly in veins in disturbed regions.

The quartzite-pebbles are light-grey, red, or liver-coloured. They are sandstones which have been indurated by the deposition of secondary silica on the original grains, whose outlines are frequently recognisable by a coating of ferric oxide (6197). One specimen (6191) consists of more or less rounded grains of quartz cemented by brown isotropic interstitial matter.

The cherts are usually black or yellow, with occasional patches and streaks of red. They sometimes contain areas of crystalline quartz, and, less frequently, drusy cavities lined with small crystals of quartz. No hard and fast line can be drawn between the cherts and jaspers. The black cherts are represented by specimens from Ben More, Coigach, Ross-shire (3894, 3937), and from Cape Wrath (6351). They consist of crypto- or micro-crystalline silica, and are frequently traversed by veins of crystalline quartz. Pseudomorphs in the form of rhombs, wholly or partly composed of ferric oxide, are often present. They doubtless indicate the presence of ferriferous carbonates such as are commonly found in cherts associated with sedimentary deposits. The sections of chert have been carefully searched for organic structures, but up to the present nothing definite has been found. The structures represented in Plate L., Fig. 1, occur in a pebble from Ben More, Coigach.

It has somewhat the appearance of a silicified oolite. The irregular oval grain near the centre of the right-hand half of the figure shows traces of concentric structure at the margin. The interior is formed of clear crypto-crystalline silica. Immediately below this is another grain without any definite radial or concentric structure. It is circular in outline, and appears to be made up of a number of small spherical bodies, the sections of which measure .04-.05 mm. in diameter. Traces of similar bodies can be made out in other portions of the slide.

Dr. Hinde has shown* that the colloid silica of sponge-spicules frequently passes into a globular form. The globules, which may occur singly or in groups, vary in size from .0014 to .045 mm. The peculiar bodies in these Torridon pebbles are on the average somewhat larger than the globules described and figured by Dr. Hinde, but they agree with them as regards their mode of aggregation. Somewhat similar bodies have been described by Vogelsang† in a silicified rhyolite from Hungary.

The yellow or buff-coloured cherts are composed of crypto- and micro-crystalline silica. Some of them (6353) consist of well-rounded grains of amorphous chert embedded in a chalcedonic matrix.

Pebbles of jasper are common in the Torridon conglomerates. They consist of crypto-crystalline and micro-crystalline silica often deeply stained with ferric oxide. Brecciated structures are frequently recognisable. A specimen from Cape Wrath shows a well-marked spherulitic structure. The central portions of the spherulites (Plate L, Fig. 2) are formed of clear, crypto-crystalline silica, in which a few small deeply-stained spheres may sometimes be observed. The marginal portions of the spherulites are also deeply stained. They consist of crystals which interfere with each other laterally, and are so arranged that their optic axes are approximately coincident with the radii of the sphere. The intervening spaces are filled with crystalline quartz containing scattered specks of ferric oxide. The individual crystals which form the peripheral portion of a spherulite are, as a rule, prolonged beyond the deeply-coloured zone so as to form a part of the unstained interstitial aggregate. This pebble, so far as structure is concerned, has many points of resemblance to the spherulitic felsites of the "Lea Rock" type, and as such felsites occur amongst the pebbles of the Torridonian

* "On Beds of Sponge-remains in the Lower and Upper Greensand of the South of England," *Phil. Trans. Roy. Soc.*, Part II., 1885.

† *Die Krystalliten.*

conglomerates the question arises as to whether it may not be a silicified rock of that type. The impregnation of trachytic and rhyolitic rocks by secondary silica is known to take place, and occasionally even the felspars of such rocks have been replaced by quartz. It is quite possible, therefore, that some of the jasper pebbles may represent silicified felsites.

The felsites are dark-purplish compact rocks, usually less red in colour than the jaspers, but not always to be easily distinguished from them. They consist of porphyritic crystals and crystal-groups of felspar in a spherulitic, micro-pegmatitic, micro-granitic, or micro-poikilitic ground mass.

Spherulitic structures are well represented in specimens from the neighbourhood of Kinlochewe (4201) and Applecross (6189). Figs. 1 and 2, Plate LI., represent portions of the latter rock. Some of the structures in this rock are identical with those of the Tertiary Hungarian liparites described by Vogelsang. They furnish, therefore, a striking illustration of the uniformity of volcanic phenomena throughout geological time.

The oldest components (6189) of this rock are certain phenocrysts of quartz and felspar. These are embedded in a matrix which shows various forms of intergrowths of quartz and felspar, as well as a certain amount of micro-crystalline interstitial matter, in which traces of perlitic structure may be recognised. Next in order of formation to the phenocrysts come spherulites of the type represented in Fig. 2, Plate LI. These show radial and concentric structures, but do not give a black cross in polarized light. They are often irregularly polygonal in outline, and sometimes give off branches in which a plumose or sheaf-like arrangement of the doubly refracting substance and also of the trichites may be seen. The spherulites in question and the branching processes connected with them are exactly similar to the corresponding structures in the slides of a rhyolite from Szanto, Hungary.

As the process of consolidation continued, spherulites of the type represented in Fig. 1, Plate LI., were formed. These frequently enclose fragments of the earlier and more deeply-stained structures, as well as phenocrysts of quartz, one of which in the form of a rounded grain is represented in the figure. They consist of two substances, felspar and quartz, and the radial structure is due to the fact that the felspar takes the form of thin and often branching fibres which run out from the centre towards the circumference.

The separation of the felspar from the quartz in the central parts of the spherulite can only be made out by using the Becké effect, but in the narrow zone which surrounds the main spherulite (Fig. 1, Plate LI.) it is quite distinct. Here the distribution of the felspar is rendered visible by red pigment which is not present in the quartz. It will be seen that the felspar takes the form of microscopic trees or bushes, which have their roots, as it were, in the main body of the spherulite. This narrow zone clearly proves that the later stages of spherulite-building were characterised by a well-marked separation of the two minerals, quartz and felspar, of which the spherulites are composed. Other portions of the slide illustrate the same point in a still more striking manner. Thus, the feather-like patches seen in the upper part of Fig. 1, Plate LI., consist of felspar and polarize as individuals. They lie in a matrix composed of large individuals of quartz which interlock with each other, irrespective of the distribution of the felspar substance, so that this portion of the slide may be said to possess a micro-poikilitic structure.

From the facts above described it is evident that this rock contains every gradation from an ultra-microscopic intergrowth of quartz and felspar to one in which the two minerals are clearly recognisable. The spherulites of acid rocks have been compared* with those formed during the slow cooling of eutectic compounds. A study of this specimen appears to show that the comparison was justified.

In addition to the phenocrysts and spherulitic intergrowths, there is a small quantity of micro-crystalline interstitial matter which obviously represents the latest phase of consolidation. It consists of quartz and felspar together with specks of iron-oxide, and is traversed in parts by well-marked perlitic cracks. These cracks sometimes traverse the individuals which form the micro-crystalline aggregate—a fact difficult to account for on the supposition that the aggregate is the result of secondary devitrification.

Other specimens of spherulitic felsite (4201) consist of phenocrysts of felspar and quartz, round which spherulites have in many cases been formed. The latter show an imperfect black cross in polarized light and have somewhat ill-defined margins. The matrix may be either micro-crystalline or micro-pegmatitic. The marginal portions of the spherulites are micro-pegmatitic intergrowths of quartz and felspar, and the coarseness of this structure decreases towards the centre until it becomes unrecognisable. The conclusion that the central parts of the spherulite are formed of ultra-microscopic intergrowths of a pegmatitic character is therefore irresistible. This specimen (4201) is also interesting as furnishing evidence of the formation of micro-pegmatite at two distinct stages in the process of consolidation, for in one or two cases small patches of micro-pegmatite form the nuclei of spherulites.

The other felsites of which sections have been prepared may be described collectively. Phenocrysts are often though not always present. They consist of oligoclase in crystals, crystalline fragments, and crystal-groups, and also of orthoclase, which is, however, much less common and often intergrown with a plagioclase felspar (micro-perthite). Ferro-magnesian minerals are never recognisable, and must have been almost entirely absent. Their former presence is suggested by the occasional occurrence of chlorite and epidote. Quartz has not been observed as a phenocryst.

† *British Petrography*, p. 402.

The ground mass which always makes up the greater portion of the rock can in general be resolved with high powers into an aggregate of quartz and felspar with which some grains of magnetite and specks of iron-oxide are associated. Micro-pegmatitic and micro-poikilitic structures are common; micro-granitic structures rare. One specimen from Applecross (6196) is mainly composed of micro-pegmatite of so fine a grain that its true character can only be recognised with high powers. In this rock the following sequence of events is recorded. First a few small idiomorphic felspars were formed, then the main mass, which was probably an eutectic compound of quartz and felspar, consolidated as micro-pegmatite.

Micro-poikilitic structure is well seen in another specimen from Applecross (6188). A few phenocrysts of felspar occur in this rock, but the main mass is a micro-poikilitic aggregate. Quartz forms, as it were, the substratum of this rock, so that if the felspar and iron-ores were removed a spongy mass of quartz would remain retaining the original form of the specimen.

In most of the rocks from which sections have been prepared, the fact that the ground mass is an aggregate of quartz and felspar can be made out with high powers. This, however, is not always the case. In one specimen (6192), which shows well-marked fluxion structure, the matrix is crypto-crystalline. A few phenocrysts of felspar are present, and the flow-structure is indicated by grains of iron-oxide and by thin micro-crystalline folia which are arranged parallel to each other throughout the slide.

These felsites have been described at some length because of the interest attaching to them on account of their age. They occur as pebbles in a pre-Cambrian group of sedimentary rocks, and must therefore have been derived from a still earlier formation, of which no other trace has been found in the north-west of Scotland. They are identical in all essential respects with the felsites belonging to the Uriconian series of Shropshire.

Apart from the fragments occurring in the basal breccias, schistose and highly metamorphic rocks are rare in the Torridon conglomerates. The collection of the Geological Survey includes a fine-grained pinkish quartzo-felspathic mica-schist (3895, Ben Slioch, Loch Maree), a fine-grained quartz-magnetite-schist (6176, Applecross), a medium-grained silvery mica-schist (6378, south-west side of Loch Maree), a bright-green rock composed of quartz and fuchsite (6354, Cape Wrath), a quartz-tourmaline rock (6179, Applecross), and two or three rocks, mainly composed of quartz, showing marked signs of dynamic action (6181, 6186, Applecross).

The quartz-fuchsite-rock bears a most striking resemblance to the green aventurine said to come from the Bellary district in Southern India. It is composed of micro-crystalline quartz and a bright-green biaxial mica, which gives the reaction for chromium in the borax bead, and shows the following colors:—x, greenish-blue; y, yellowish-green; z, green. The x-colour for fuchsite is described by Dana as robin's-egg blue, a statement which is somewhat puzzling to British readers, as our robin lays eggs of a dull white colour marked with reddish spots, but which receives a perfect explanation when it is remembered that the American robin is a thrush. The peculiar colour is that of most thrushes' eggs.

The quartz-magnetite rock is composed of micro-crystalline quartz associated with grains, crystals, and crystalline groups of magnetite. It possesses a well-marked parallel structure which is brought out by the distribution of magnetite. This pebble must have been derived from rocks allied to those already described as occurring in the altered sedimentary series of the Loch Maree district.

The quartz-tourmaline rock is compact, dark, composed of micro-crystalline quartz and grains of brown tourmaline. It is probably a tourmaline-hornfels, due to contact action of granite upon a sedimentary rock. It is very similar to rocks occurring round the granitic masses of Cornwall, and also as pebbles in the Triassic conglomerates of Central England and in the drifts of the South of England.

(2) *Mineral Constituents derived from Older Rocks.*—In those areas which have not been affected by the post-Cambrian earth-movements the mineral constituents are, as a rule, allothigenic and allothimorphic. Secondary enlargement of quartz-grains and the development of minute scales of mica in the felspars are the only important agencies which have modified the original constituents. But in the moved areas the original clastic grains have been modified both in external form and internal structure. The nature of these modifications will be described under the different minerals.

Clastic quartz occurs abundantly in all except the finest-grained argillaceous deposits. The larger grains (1 mm. or more) are often well rounded, but the smaller (.1 mm. or less) are, on the contrary, always angular. The minute hair-like inclusions so characteristic of the blue quartz of the pyroxene-gneisses are very rare. The behaviour of the quartz when subjected to anisotropic stresses is well illustrated by many specimens from the neighbourhood of Kinlochewe (3713-3731) and Loch Kishorn (2263-2269). The first evidence of strain is the absence of definite extinction under crossed nicols. Sometimes the shadows sweep uniformly over the section; at other times the grain is divided into stripes or patches which have a fairly uniform orientation, the adjacent portions being separated by a narrow zone in which the extinction positions change rapidly. A difference of 18° or 20° may sometimes be observed between adjacent patches of what was originally a clastic grain with uniform extinction. If examined in convergent polarized light the strained portions give the figure of a biaxial mineral with small optic axial angle.

As deformation progresses more important changes take place in the external form and internal structure of the grains. They frequently become lenticular, and the original grain may be replaced by a micro-crystalline (granulitic) or crypto-crystalline (mylonitic) aggregate. Not infrequently a large individual may be converted into smaller lenticular individuals separated by micro- and crypto-crystalline material. As these changes take place the original grain often becomes frayed at the edges and loses itself gradually, so to speak, in the secondary granulitic or mylonitic substance, which frequently constitutes a considerable portion of the rocks in which these phenomena are seen.

In the coarser-grained rocks felspars are almost as abundant as quartz. Microcline, microcline-microperthite, orthoclase, and oligoclase have been recognised. The characteristic felspar of the red sandstones or arkoses, which form such an important feature of the Torridonian series, is microcline and microcline-microperthite. The other felspars are, as a rule, much more altered than the microcline, and more deeply stained with ferric oxide. On this account they are frequently undeterminable. Oligoclase may, however, often be recognised, and it is probable that most of the altered felspar belongs to this species.

When subjected to deforming stresses felspar does not behave in the same way as quartz. It is more liable to actual fracture, and broken fragments, which evidently belonged to one individual, are frequently seen, under the microscope, to have been separated from each other. Individuals of quartz have often changed their forms by passing into aggregates without any separation of the constituents of the aggregate. Felspars, on the contrary, have changed their forms by actual fracture, and the authiclastic fragments have often been dragged apart by internal movements in the rock-mass. In the rocks with a pronounced fluxion (micro-flaser) structure lenticular grains of felspar with tail-like endings, largely composed of broken fragments of the grain itself, may frequently be observed.

The felspars often show the micaceous type of decomposition, and much of the sericitic mica in the sheared varieties of the coarser rock has doubtless been formed at their expense.

Clastic micas occur in the finer-grained sandstones and sandy shales. Both brown and white micas are present, and the former is often as abundant as the latter. Grains of epidote are common in many of the finer-grained sediments, and especially in the rocks belonging to the base of the series.

The heavy minerals so commonly found in the finer-grained sandstones of all geological periods occur also in those of the Torridonian series. They include magnetite, ilmenite, sphene, garnet, tourmaline, zircon, and rutile. Black bands mainly composed of titaniferous iron-ore occur in the Middle Torridonian group of Skye (5072)*, and also in beds provisionally referred to the Upper Torridonian group in Crowlin Island, south of the Applecross peninsula (8761).

* These grains were roughly isolated and partially analysed by Dr. Pollard. Iron reckoned as Fe_2O_3, 73·7; TiO_2, 14·1; SiO_2, 9·8; Al_2O_3 &c., 2·2; loss, ·6. They are but slightly affected by a weak magnet.

(3) *Minerals Developed in the Rocks.*—The very important question of the relation of the Torridonian formation to the crystalline (Moine or Eastern) schists is expressly omitted from consideration here. Leaving out of account, therefore, certain crystalline rocks which may eventually be accepted on all hands as Torridonian, those which remain do not show any striking development of new minerals unless the secondary mylonitic and granulitic aggregates, containing mica and chlorite, of which the sheared rocks are often largely composed, be included under this head.

Sericitic mica is abundant in all the sheared rocks. It has evidently been developed at the expense of the felspar, and coats the planes of differential movement. Chlorite is common in the green grits and fine-grained greywackes which occur so largely in the Lower Torridonian rocks of Skye and the district about Loch Carron.

The intensely-sheared epidotic grits which occur at the junction of the Torridonian and Lewisian Gneiss at Fernaig (Loch Carron) contain numerous idiomorphic crystals of magnetite. As these crystals vary considerably in size and are quite unlike the clastic grains of titaniferous iron-ore above referred to, it is probable that they have been developed *in situ*. The secondary micro-crystalline mosaic of this rock (4102), though fine in grain, has all the distinctive characters of a true crystalline schist. Detached flakes of chlorite are scattered through it exactly in the same way as those of mica in typical Moine-schists.

GENERAL DESCRIPTION OF THE ROCKS.

The rocks include all types of mechanical sediment from the finest argillaceous deposits to the coarsest conglomerates and breccias. Calcareous deposits are represented only by a few thin bands of calcareous grit and impure limestone. The Upper Torridonian group of Cailleach Head (Loch Broom) contains phosphatic matter in impersistent bands and nodules.

The red felspathic sandstones or arkoses which constitute so large a part of the series between Cape Wrath and Applecross resemble those of other great continental formations both in their petrographical characters and in their relation to the underlying floor of Lewisian Gneiss. The principal constituents are quartz, alkali-felspar, and oligoclase. The red colour is due partly to a staining of the more or less altered felspars or fragments of felsite, which sometimes form a not inconsiderable portion of the rock (8751), and partly to a thin pellicle of ferric oxide coating the individual grains. This coating is probably the result of subaerial decomposition on the old land surface from which the materials were derived. The basal breccias which often flank the buried mountains are, as already explained, of the nature of scree material. They consist of fragments of the local rocks embedded in a sandstone matrix. The conglomerates, on the other hand, are probably torrential deposits brought down from a district very different in geological structure from that of the area in which the Lewisian Gneiss occurs. Some information as to the nature of this district is furnished by the pebbles, of which a description has already been given. It must have contained representatives of sedimentary, plutonic, volcanic, and metamorphic rocks. In interpreting the evidence furnished by the pebbles, it must, of course, be remembered that some of these may have existed as pebbles in still earlier formations. Such rocks as quartzite, chert, jasper, tourmaline-hornfels, and vein-quartz possess great powers of resistance, and pebbles formed of them have often been handed on from one formation to another during the progress of geological time.

Although red rocks constitute a very large part of the Torridonian formation, they by no means make up the whole. Dark shales occur both at the base and at the top of the series in certain localities. The basal shales are well seen in the narrow strait, dry at low tide, separating the Isle of Fladda from the northern part of Raasay. They are indurated so as to resemble slates, but they do not possess a true cleavage. The upper junction with the red beds is here well exposed, and the abrupt change in colour is very striking. At the upper limit of the dark shales there are beds of a grey, banded calcareous sandstone, about two or three inches in thickness. This rock (5876, 5877) is composed of angular grains of quartz and felspar (.1-.2 mm.), flakes of biotite and white mica, a few grains of garnet, sphene, iron-ores, and epidote, and a matrix of calcite. The heavy minerals and the micas are arranged in layers parallel with the stratification, and doubtless owe this mode of distribution to the sorting action of gentle currents. Portions of the calcareous matrix possess a very peculiar granular structure. They are composed of more or less rounded grains of calcite of approximately uniform size (about .02 mm.). The grains occur singly and in clusters. The meaning of this structure is very obscure. It may possibly be organic, but, if so, the nature of the organism is unknown.

The beds of calcareous grit are interstratified with the upper part of the black shales, and the portion of the series containing them is immediately succeeded by red felspathic sandstones. The abrupt change in colour certainly indicates a sudden and important change in the conditions of deposition, probably allied to that indicated by a similar change in colour at the junction of the Keuper and Rhætic series in England.

The shales of the Upper Torridonian group are well developed at Cailleach Head, Loch Broom (8758, 8760), where they are associated with micaceous sandstones containing two micas (8759). One specimen (8760) is of great interest on account of the presence of black phosphatic lenticles. It is distinctly laminated, and contains minute grains of quartz, felspar, and epidote (.05 mm. or less) associated with two micas. The lenticles ($1 \times 1 \times \frac{1}{4}$ in.) consist of the finer portions of the sedimentary material cemented with brown amorphous phosphate. In transverse sections the lamination of the rock can be distinctly traced into the lenticle, but the laminæ are further apart in the lenticle than they are in the shale, thus proving that there has been greater compression in those portions of the rock which have not been cemented by phosphate.

The general appearance of the phosphate is precisely similar to that of the concretions which occur in many geological formations, and, as is almost always the case, it is associated with some carbonate. Under these circumstances it becomes interesting to search for traces of organic structure. Under the microscope the amorphous brown phosphate is seen to contain minute spherical bodies (about .01 mm.), which occur both singly and in groups; also brown fibres, about .004 mm. in breadth, and of lengths varying from a few hundredths to several tenths of a millimetre. These fibres may be either straight, curved, or even looped.

Seeing that phosphates of this type are always associated with organisms, it seems impossible to avoid the conclusion that these peculiar structures are of organic origin; but the evidence at present available is not sufficient to indicate the nature of the organisms.

The facts above described clearly indicate that a concentration of phosphatic matter took place during or immediately after the accumulation of the sediment. A similar concentration has occurred in sedimentary rocks of many different geological periods; but in most cases the loose deposit in which the action took place has been winnowed away by a process of contemporaneous erosion, so that the nodules are not, as a rule, embedded in their original matrix as they are in this case.

The Lower Torridon groups of the thrust areas, extending from Loch Kishorn to the Point of Sleat in Skye, include an extensive series of grey and greenish-grey, fine-grained schistose grits or greywackes. These rocks answer to the "grauwacke-schiefer" of German petrologists. They alternate with other cleaved rocks which, in their original condition, must have been sandy shales. In these rocks the dominant felspar is plagioclase instead of microcline, and epidote and chlorite are not uncommon. The lowest beds in this district are often extremely rich in epidote, and on this account are often referred to as epidotic grits and conglomerates.

THE DYNAMIC METAMORPHISM OF TORRIDONIAN ROCKS.

The effects of dynamic metamorphism upon the Torridonian rocks are very marked in certain places. A series of specimens (2263-2269) from the district of Lochs Kishorn and Carron, collected by Sir Archibald Geikie, the Director-General, well illustrates these effects on medium-grained grits, essentially composed of quartz, microcline, and oligoclase. The least altered rocks are easily recognisable as grits, but the outlines of the grains are not so well defined as in the unaltered specimens, and a marked fluxion structure is seen on transverse surfaces. The quartz grains have often been drawn out into lenticles and even into thin folia which wind round "eyes" of pink felspar (2263). The hand specimens are traversed by planes of schistosity which are glazed with sericitic mica (2263 and 2266), and in extreme cases may be termed sericitic schists (2269). Under the microscope the rocks are seen to consist of more or less deformed grains of quartz, alkali-felspar, and oligoclase, with a variable amount of secondary crypto- or micro-crystalline material. The series illustrates all the points referred to in describing the effects of dynamic action on quartz and felspar. The secondary crypto- or micro-crystalline material with which the sericitic mica is associated is of special interest because it approximates, in structure, to crystalline schists of the Moine type. It suggests the conclusion that, if the deformation had taken place under a greater load, and therefore in all probability at a higher temperature, a holocrystalline schist of true Moine type might have been produced.

Another important series illustrating the effects of dynamic metamorphism near the inverted base line of the Torridon Sandstone near Coulin, over the Kinlochewe thrust-plane, was collected by Dr. Horne (3713-3723). The first of the series is from a point 40 feet below the junction line, and the others follow in order up to the junction of the two formations. The locality is 3 miles south of Kinlochewe. The rocks vary in colour from pale pinkish-grey to dark greenish-grey. Dark greenish rocks, weathering to a light cream or buff colour, predominate. They are all more or less schistose, and in texture vary from medium-grained to compact. When the schistosity is even and regular the finer-grained rocks break with a platy fracture reminding one of that of the Moine-schists. The constituents are quartz, microcline, oligoclase, white mica (mostly sericitic), iron-ores (scarce), and a micro-crystalline or crypto-crystalline matrix. Microcline is the dominant falspar. The larger constituents show the pressure phenomena already described, and the quartz grains especially often merge into the crypto-crystalline matrix in such a way as to show that they have contributed to its formation. Flakes of clastic mica may be recognised in some of the finer-grained specimens, but the sericitic mica which is associated with the matrix is mainly of secondary origin.

The matrix gives a felsitic appearance to many of the hand specimens in which the original structure has almost entirely disappeared. Under the microscope it cannot be resolved into distinct grains. The structure is crypto-crystalline verging on micro-crystalline. It is associated with streaks of sericitic mica. This matrix in which the relics of the original grains are embedded represents in part the finer-grained sedimentary material and is in part of secondary mylonitic origin.

Looking at the series as a whole, it is noticeable that the least-altered specimens occur furthest from the junction line of the Lewisian and Torridonian rocks, while the most altered specimens are those from its immediate neighbourhood. The increase in alteration is not, however, uniform. Bands exhibiting the effect of intense shearing alternate with others in which the effects of shearing are much less marked.

CHAPTER XVII.

CAPE WRATH TO LOCH LURGAN*.

The district described in the present chapter includes a strip of country which runs along the western margin of the counties of Sutherland and Ross from the northern cliffs of Cape Wrath, across the Parph, Ederachillis, and Assynt to the chain of lakes that runs through the heart of Coigach. Several easily separable tracts of Torridonian strata can be distinguished along this belt. At the northern end a group of much-faulted outliers of these rocks covers most of the ground between the northern cliffs and Loch Inchard. After a considerable interval in which the Torridonian covering has been completely removed from the plateau of gneiss a detached outlier is found in Handa Island. To the south of another intervening tract of gneiss we come upon the huge detached outliers of Assynt with the long outlier of Rhu Stoer, while still further southward the Torridon formation gathers into a more continuous development and sweeps up into the great mountainous range of the Coigach Hills.

Cape Wrath District.—The area between Cape Wrath and Loch Inchard includes near its northern limits the desolate tract known as the Parph—for the most part a barren treeless waste, where dreary expanses of wet peat-moss alternate with bare and rocky or peat-covered hills. These hills, as is usually the case with Torridonian mountains, have no definite arrangement, but form isolated clusters or solitary peaks—the denuded fragments of the once widespread covering of sandstone. Of the former type of ground, the hilly district immediately north of Strath Sinairidh is the best example. It includes Beinn Dearg Mhor, Meall Dearg, Meall na Moine, and Creag Riabhach, all of which reach a height of over 1500 feet. Fasbheinn and Farmheall are the most conspicuous of the solitary peaks, the latter, with its capping of Cambrian quartzite, rising to 1709 feet. In striking contrast to the tameness and monotony of the interior are the stupendous vertical precipices of the northern coast-line, 600 to 700 feet in height, formed by the nearly horizontal sandstones of the Clo Mhor, between Cearbhag Bay and the north end of Sgribhinn. Less lofty but equally precipitous cliffs of purple

* By L. W. Hinxman, with notes by B. N. Peach and C. T. Clough. The district described in this chapter lies in the ground represented on Sheets 101, 107, 113, and 114 of the Geological Survey Map of Scotland on the scale of one inch to a mile ($\frac{1}{63360}$).

grit and sandstone extend along the greater part of the western shore-line between Cape Wrath and the mouth of Loch Inchard. They rise directly from deep water and present a steep unbroken front, save where a narrow gully marks a line of fault, or a streamlet has cut a deep ravine down to the sea.

The Torridonian rocks of this northern portion of the district have been divided into three zones possessing well-marked characteristics. The distribution of these zones is shown on Sheet 113 of the Survey Map, where they are distinguished by the letters t′, t″, t‴, and their order and general lithological characters are shown in the subjoined table:—

		Average Thickness.
3. Upper Zone (t‴)	Fine-grained, friable, banded and mottled, purple and yellow false-bedded sandstones.	250 feet.
2. Middle Zone (t″)	Coarse, false-bedded sandstones and grits, with pebbly bands at several horizons.	1000 ,,
1. Lower Zone (t′)	Coarse pebbly conglomerate.	100 ,,

Although the upper and middle zones may be regarded as probably equivalent to portions of the Aultbea and Applecross groups respectively, it must be understood that the sub-divisions given above are only of local application, and do not correspond to the three main groups into which the Torridonian series of the more typical region further south has been divided. The basal conglomerate can be traced more or less continuously throughout the tract near Cape Wrath, but ceases to form the base of the series further to the south. Lower strata continually come in as the middle or arkose group thickens, and these conglomerates, while preserving their relative position, pass up into the series, thin out, and finally cease to be noticeable as a horizon south of the Quinag area.

(1) Basal Conglomerate.—This is a coarse accumulation of well-rounded pebbles ranging in size from that of a hazel-nut up to fragments 4 inches in length, set in a purplish or red sandy matrix composed of rounded grains of quartz and felspar. So compact is this matrix that, where the conglomerate is undisintegrated, the pebbles are found to break across more readily than to part from it along a joint-face.

An examination of the pebbles at various places shows the great majority of them to be composed of vein-quartz or red jasper, the former predominating. A small proportion are of quartzite, chert, and felsite, and occasional fragments of mica-schist, gneiss, and a dark-greenish porcellanous volcanic rock are also met with. The origin of most of these pebbles from some distant source has already been referred to, while their large size and uniformly well-rounded appearance seems to indicate the near vicinity of a shore-line and the frequent influx of stream-borne material.

The following localities are those where the basal conglomerate is best seen and most typically developed:—Between Dail and Cnoc na Ba Ruaidhe at the mouth of the Kyle of Durness; immediately south of Cape Wrath Lighthouse; round the base of Fasbheinn, where the zone reaches its maximum thickness of 180 feet; Sheigra and Ballnacraig, along the north shore of Loch Inchard; north of Kinloch Bervie, where it is from 50 to 100 feet thick and contains some pebbles of green schist; along the north face of Creag Riabhach (5-100 feet); in the Achricsgill Water at the road side near Rhiconich; and on the west and north faces of Farmheall.

(2) Grits and Sandstones.—The rocks included in the middle zone, which occupy by far the largest area of the three divisions, consist of a series of red, purple, and chocolate-coloured coarse sandstones and grits, with occasional seams or thin bands of fine-grained red and purple sandstone and frequent pebbly bands. These last are especially developed near the base, either as beds of conglomerate or as lines of small, less completely rounded pebbles scattered sparsely through a sandy matrix. They are distinguished from the basal conglomerate by the smaller size of their pebbles and the frequent intercalations of grit and sandstone in them. False-bedding characterises the whole of the finer-grained members of the series, but is most frequent in the upper portion. These planes, due to current action, are often inclined at a considerable angle to the true bedding planes.

The rocks of this zone are well exposed along the cliffs of the west coast between Cape Wrath and Sheigra, and on the north from Bagh Cearbhag to the Geodha Sligeach, where they form a range of vertical precipices which at Clo Mòr reach a height of more than 600 feet. False-bedding is conspicuous in the finer sandstones along the top of these cliffs. It dips in the opposite direction to the true bedding, to which it is inclined at angles of 10°-15°. The rocks can also be studied on the summit and western peaks of Farmheall, on Fasbheinn, and on the hills on either side of Strath Sinairidh. The thickness of the zone on the west side of Beinn Dearg Mhor is at least 1100 feet, but decreases to the eastwards, and on Farmheall does not exceed 900 feet.

(3) Banded Sandstones.—The highest zone of the series is made up of fine-grained, friable, striped and mottled, purple and yellow sandstones, with occasional intercalations of grit. These strata usually occur in thin layers, and are false-bedded throughout. Their friable nature causes them to disintegrate readily, and the amount of loose crumbly debris that

covers the surface on the hill-tops where they occur suggests that a large portion of them may not improbably have been removed by denudation prior to the laying down of the Cambrian quartzite upon them, as well as since their re-exposure after the removal of the quartzite. This zone caps the summit of most of the higher hills of the northern area, and forms the upper 50 feet or so of the cliffs between Bagh Geisgeach and Geodha Ruadh an t' Seannabhaid, four miles south of Cape Wrath.

A reference to Sheets 113 and 114 will show that the areas occupied by Torridonian strata south of Cape Wrath are arranged in roughly parallel bands that stretch across the country from south-west to north-east. These areas are in every case determined by faults that bound them on one or more sides. These dislocations, by letting down the sandstones against the harder underlying gneiss, have doubtless preserved them to some degree from the effects of denudation. The small outlier of conglomerate above Loch na Gainmhich, between Fasbheinn and Beinn Dearg Bheag, is indeed the only outlier without any flanking fault where the whole of the remnant of the Torridonian covering can be seen in its original unconformable relation to the gneiss below. These boundary faults arrange themselves in two well-marked conjugate systems, their general trend being respectively from south-west to north-east and south-east to north-west. The downthrow of the north-west faults is invariably to the east, and these dislocations appear to be of later origin than the north-easterly series, which in several instances have been shifted or cut off by them.

Six to eight of the north-east lines of fracture have been mapped from Cape Wrath southward. The first of them crosses the headland of the Cape from sea to sea and lets down two small patches of the basal conglomerate, one of which is well seen capping the gneiss along the roadside near the lighthouse gateway, where it consists of a thin cake of coarse conglomerate, disintegrating into loose sand and pebbles, some of which are from two to four inches in length. The next fault, a mile further south, is of much greater magnitude, and produces a striking feature on the coast. An almost vertical fault-face of gneiss-walls is there seen to run up a narrow gorge for some distance from the sea, the downthrow being, as in the first case, to the south. The course of this fault inland is for the most part conjectural, but it probably reaches the northern coast and forms the straight cliff-feature which bounds the Geodha na Seamraig on the west.

From Bagh Geisgach another fault, also with a southerly hade, traverses the col between Sithean na h-Iolaire and Cnoc a' Ghiubhais, bringing the banded sandstones of the highest zone down against the pebbly grits of the former hill, and shifting the main outcrop of the conglomerate more than half a mile back to the east along the eastern slope of Cnoc a'

Ghiubhais. These banded purple sandstones continue southwards along the coast and form the upper part of the cliffs as far as Geodha Ruadh an t-Seannabhaid, where they are cut off by a small fault running in an E.S.E. direction. The false-bedded grits and sandstones of Cnoc a' Geodha Ruaidh dip steadily to the south at 9° to 12° till within a short distance of the mouth of the Strath na Caillich burn, where they become much disturbed. Finally the basal conglomerate, brought up by a small fault and a reversed dip to the north, is seen faulted against the gneiss by a powerful dislocation with a downthrow to the north, which runs eastward past the foot of Loch Geisgeach and loses itself under the peat-mosses of the Parph.

A narrow tongue of gneiss separates the Geisgeach outlier from the next Torridonian area to the south. This is the most important development of this formation in the Cape Wrath area, since it covers a space of some 25 square miles, divided into two nearly equal parts by Loch Sandwood and Strath Sinairidh. The area is bounded on the north by the natural outcrop of the basal conglomerate, which runs north-eastwards with a sinuous course from the mouth of Loch Sandwood to the Chearbhaig burn, where it is shifted ½ mile to the north by a small cross fault. It then sweeps round the lower contours of Maol Meallach till it is cut off by the large fault which forms the eastern limit of the area as far as the foot of Creag Riabhaich. This fault, which thus throws back the Torridonian outcrop fully three miles to the south, is perhaps the most powerful of the north-east system of dislocations, and its downthrow on Creag Riabhaich, where it brings together the highest and lowest zones of the Torridonian, must be at least 1000 feet. It is continued over the summit of Beinn Dearg Mhòr, letting down the banded sandstones against the grits of the middle zone, and crosses Strath Sinairidh, after which its course is concealed by the thick covering of peat and drift that surrounds Loch Mhòr a Chraisg.

Less than two miles further to the east, another parallel fault with a downthrow to the north crosses the area, and shifts the outcrop of the conglomerate along the north side of Meall na Moine. The course of this fault west of Strath Sinairidh is marked by the strong feature seen along the hillside between Loch Coir à Phris and Loch Carn à Mharbhais Aite, where the dislocation runs along the centre of a shallow synclinal trough. On the north-eastern slopes of Meall na Moine the conglomerate is again cut off by another fault hading north, which forms the boundary of the area for four miles westwards as far as the small burn flowing into the head of Loch Carn à Mharbhais Aite. From this point the natural base line of the Torridonian extends westwards, shifted by two or three cross faults, to the head of Loch Innis na Ba Buidhe, where it is once more truncated by the Meall na Moine fault referred to above. The basal conglomerates are well exposed on the hill slope north of the Free Church, where they dip north and north-west at 5°-12°.

The western boundary of this tract of Torridon Sandstone is largely determined by the powerful fault that runs S.S.E. from Rudh' an Fhir Leithe to Kinloch Bervie, south of which its course is probably indicated by the straight western shore-line of Loch Inchard and the valley of the Garbet Beag river. For nearly three miles north from Loch na Claise, and again along the east side of Cnoc Poll a' Mhurain, the grits and sandstones of the middle zone are brought against the gneiss; but, as the fault runs for the most part along a peaty hollow, the actual junction of the two formations can nowhere be seen. Between Blarmor and Sheigra, and along the coast from the latter place to Ruadh' an Fhir Leithe, the lower Torridonian strata rest unconformably upon the gneiss on the west side of the fault, forming two irregular patches much cut up by small parallel cross faults. Coarse pebbly grits and conglomerates dipping north-west at 8°-15° rise in a series of craggy knolls and escarpments about Blarmor and Ballnacraig, and the unconformable junction is well seen along the base of the cliff at Sheigra and on the shore at the mouth of the Loch Poll à Mhurain burn. Other small outliers of conglomerate occur on Eilean na h'Adaig (two miles north-west of Kinloch Bervie) and among the blown-sand hills at Old Shore More.

The southernmost of the Torridonian areas between Cape Wrath and Loch Inchard lies immediately to the west of the Durness and Rhiconich road, and includes the conspicuous ridge of Farmheall and the lower heights of An-t-Socach, Creag Riabhach, and Meall na Moine. In this outlier also the effect of faults in producing an extremely irregular outline is well shown. By a series of parallel north-east faults the outcrop of the zones is continually shifted, as may be seen round the flanks of An-t-Socach and along the north side of the outlier, though there is reason to suppose that the irregularity may be here due in some measure to the uneven surface of the gneiss on which the Torridonian strata were laid down. The basement bed along the north face of An-t-Socach is a coarse breccia containing large angular fragments of the underlying gneiss. This is the only locality in the Cape Wrath area where such a type of basal breccia has been observed, though it is of such frequent occurrence as a local base to the Torridonian rocks further south, where it invariably indicates an uneven surface. It may be mentioned that at the head of the Allt Garbh, half a mile to the west of An-t-Socach, a small dome of gneiss, from which the beds dip away on every side, protrudes through the conglomerate and affords the first direct evidence of such an uneven floor. Another small inlier of gneiss will be noticed among the conglomerates about ½ mile west by north of Loch Gainimh, and though it is shown on the map as cut off on the south side by a fault, it may not improbably also represent a prominence of the pre-Torridonian surface.

The south-eastern limit of the Cape Wrath area is marked by the powerful line of dislocation that runs from the head of Loch Inchard to the north coast at Smoo and defines the eastern side of the Durness basin. The line of this fault almost coincides with that of the high road for some distance westwards from the Gualainn House. At the point where it leaves the road, about two miles north of Rhiconich, the basal conglomerate, here faulted against the gneiss, is well exposed in the deep ravines cut by the two streams that here join to form the Achrisgill Water. Coarse conglomerate composed of pebbles of vein-quartz, quartzite, jasper, and felsite, from an inch to four inches in length, is seen at the waterfall, both resting unconformably upon and faulted against the gneiss. Higher up the Allt Leacach the conglomerate alternates with beds of purple grit and sandstone, one to three feet in thickness, dipping east at 6° to 11°. Similar rocks, which with a southerly dip appear along the roadside between this point and the Gualainn House, belong to the lower part of the middle zone, and are in faulted conjunction with the gneiss which is exposed on the shores of Loch an Tarbhach Mòr (three miles north-east of Rhiconich). A cross fault, which comes down to the road a few hundred yards beyond the Gualainn House, cuts off the basal conglomerate round the end of Meall na Moine, and throws down the middle grits along the flank of Farmheall against the gneiss in the hollow between the Feur lochs and the Gualainn burn. Half a mile further north the main fault leaves the road for the course of the Dionard river, and a branch fault with a contrary downthrow cuts off the Torridonian strata along the base of Farmheall. This fault has a downthrow to south-east, and brings the Cambrian grits, that rest unconformably on the sandstones over the summit of the hill, against the Torridon grits below the road. The Cambrian strata thus lie in a trough-fault at the apex of the triangle formed by the Durness basin.

In the Fasbheinn outlier, which occupies an area one mile in length by half a mile in breadth immediately to the west of Loch Airidh na Beinne, the Torridonian strata rest unconformably upon the gneiss, except at the south-east corner, where the lowest beds are cut off for a short distance by a branch of the Creag Riabhach dislocation. But for this interruption the basal conglomerate can be traced almost continuously round the hill. On the north-west face it attains a thickness of about 180 feet. The upper part of the hill is made up of the grits of the middle zone, dipping S.S.E. at an average angle of 10°.

A smaller outlier on Beinn a' Bhacaidh, one mile south-east of Loch Airidh na Beinne, shows on its western side the conglomerates resting unconformably upon the gneiss and rising in successive escarpments, their dip being to south-east at angles of 10°-15°. A few hundred yards further east they are overlain by the Cambrian quartzite, which is inclined in the same direction but at a considerably higher angle (30°-35°). The unconformable relation of these two formations is well seen here, the escarpments of Torridonian conglomerate being successively cut off by the scarped outcrop of the Cambrian quartzite. A short distance further eastwards the overlap is still more strongly marked, for the quartzite is there seen to rest directly upon the gneiss without the intervention of the conglomerate.

The powerful dislocation which crosses the Kyle of Durness at Keoldale, and runs north-west to Cearbhag Bay, throws down to the north two considerable areas of Torridonian rocks. In the smaller of these, which lies to the west and north of Dail, at the mouth of the Kyle, the basal conglomerates are well exposed at the roadside a little beyond the shepherd's house, and on the eastern side of the area near the track leading to the pier. The outcrop on this eastern side is extremely irregular, the conglomerate lying in tongues and small outlying patches among the hollows of the gneiss. An irregularity of this kind may be partly due to deposition on an uneven surface, but probably partly also to a system of small parallel faults which have shifted the outcrop and determined the steeper sides of the trough-like hollows in which the conglomerate appears.

Handa.—This island, about a square mile in extent, consists entirely of Torridon Sandstone. Its bold sea-cliffs are mostly inaccessible, but where the rocks can be reached they are found to consist of pebbly beds and coarse sandstones. An examination of the pebbles at the north-east corner of the island shows that, in addition to the usual quartz, jasper, and quartzite, the pebbles include fragments of purple and red porphyrite or felstone with pink porphyritic felspars, a porphyritic ash-like rock, and grey sedimentary and greenish-white schistose rocks. Over the greater part of the island the strata are very gently inclined or almost flat. Towards the eastern side the E.S.E. dip becomes more pronounced and rises to 20° or 25°. This increase of dip is probably due to the effect of a large fault which, running through the Sound of Handa, throws down the Torridonian strata of the island against the gneiss of the mainland. This fault is possibly a continuation of the fault that runs north-east through Loch Dubh and Loch na Gualainn to the southern shore of Loch Laxford. Several crush-lines with hade to west, marking subordinate parallel faults, are seen along the eastern side of the island.

Ben Dreavie.—An impressive proof of the denudation which the Torridonian formation has suffered is furnished by a small outlier of false-bedded conglomerate and pebbly sandstone which caps the summit of Ben Dreavie, two miles to the south of Loch Stack. This isolated patch measures no more than 450 yards in length from east to west, 260 yards in breadth, and is only 50 or 60 feet in thickness. The pebbles in the conglomerate here reach a length of three inches, and consist mainly of quartz, jasper, and purple quartzite, while the finer bands contain abundant fragments of felspar and pegmatite.

The fault with a downthrow to the south which runs along Strath an Staca, the glen to the north of Ben Dreavie, and the uneven surface of the gneiss, are together probably sufficient to account for the absence of Torridonian strata on the much higher summit of Ben Stack (2364 feet), a mile and a half to the north. But the further extension of the Torridonian rocks in this area is indicated by the purple staining of the gneiss around the outlier.

Quinag (Plate XXXI.).—A Torridonian area of considerable size and roughly triangular in shape lies between Loch Cairn Bàn and Loch Assynt, and forms the imposing mass known collectively as Quinag. This mountain rises abruptly on its northern side in two steep bluffs—Sail Garbh and Sail Ghorm—separated by the deep corrie at the head of the Allt a' Bhathaich. On the west side it is flanked by precipitous cliffs, 500-700 feet in height, forming a line of escarpment that extends north by west for upwards of two miles. The extreme summit (2653 feet) lies a quarter of a mile south of Sail Garbh, and is capped with a small outlier of the Cambrian basal quartzite, which dips in the same south-easterly direction as the underlying sandstones, but at a higher angle. Spidean Coinich, the southern peak, is also covered unconformably with 150 feet of Cambrian strata which, extending down the eastern side of the hill in a long dip-slope inclined to E.S.E. at an average angle of 15°, rapidly transgress the successive beds of the Torridonian series which dip east by south at only 5° to 6°.

The rocks included in the Quinag area may be referred to the middle or Applecross group of the Torridonian formation. They consist for the most part of massive false-bedded purple grits and sandstones with pebbly bands. On the summit of Sail Ghorm and in the upper part of the cliffs on either side of the Bealach Chornaich some beds of banded purple sandstones with seams of green and purple shale are intercalated with the grits. These seem to be of local occurrence, and are not to be regarded as belonging to a higher group.

Local basement beds of coarse conglomerate and breccia are found along the northern outcrop; and finer conglomerates composed of well-marked pebbles, and resembling the conglomerates of the Cape Wrath area, occur some 400 feet above the base along the southern slope of Spidean Coinich. The total thickness of the Torridonian strata on Sail Garbh is about 1700 feet, and on Spidean Coinich 1900 feet, this difference being probably in great measure due to the unevenness of the surface on which these sediments were laid down. A good section of the lower portion of the series is exposed in the Allt Saobhaidh Moire on the east side of Sail Garbh. The stream in the upper part of its course flows over long ripple-marked slabs of red grit and sandstone, with occasional bands of large scattered pebbles. Lower down, at the

700-feet contour-line, a small prominence of the uneven surface of the gneiss is seen protruding through the surrounding beds of coarse conglomerate and breccia, the latter of which contains blocks of gneiss 12 to 18 inches in length. The base is reached at 600 feet, and the unconformable junction with the gneiss is well seen between the burn and Loch nan Eun. The basement beds here exhibit large rounded and angular masses of gneiss scattered through a purple sandy matrix, succeeded above by coarse conglomerates dipping E.S.E. at low angles.

The Torridonian area narrows rapidly from Quinag eastwards towards Loch Glen Coul until it is completely overlapped by the Cambrian quartzite at a point half a mile east of the bridge crossing the Unapool burn. The most interesting feature of the Quinag outlier is the striking evidence which it affords of the irregularity of the surface of gneiss on which the Torridonian strata were deposited. The northern outcrop rises rapidly westwards from the 600-feet level at Allt Saobhaidh Moire to nearly 1500 feet on the north-west face of Sail Garbh. The basal conglomerate is seen in the Allt a Bhàthaich corrie, but as the observer climbs the slope of Sail Ghorm on the further side of the hollow he finds the sandstones rapidly overlapping against the flank of a pre-Torridonian hill of gneiss which rises to a height of nearly 2000 feet above the sea and about 1200 feet above the general level of the gneiss-plateau. The steep northern face of Sail Ghorm affords several good vertical sections in which the relations of the Torridonian strata with the gneiss on the sides and summit of this ancient mountain can be studied. Purple grits and sandstones with bands of shale, well up in the series, here rest on the eroded surface of the gneiss, the hollows in which are in most cases filled with a basement breccia made up of angular fragments of the underlying rocks.

On the west side of Sail Ghorm the Torridonian outcrop drops rapidly to the 1000-feet level above Loch an Leothaid. A short distance further south it is stepped down by two cross faults to the 800-feet contour-line, which it follows to the head of Gleann Leirg, where it is cut off by the fault which follows the line of the pass. The natural outcrop is seen again on the south side of the pass, but its course is for the most part concealed by moraines and drift. The base of the Torridonian series is well exposed for some distance along the roadside under Lochan na Dunaich, three miles north-west of Inchnadamff, until a small fault brings it down to the shore of Loch Assynt, a mile to the west of Skiag Bridge (two and a half miles north-west of Inchnadamff). The basement bed that here rests on the uneven surface of the gneiss is not an ordinary breccia, but consists of large well-rounded pebbles and angular blocks of gneiss scattered irregularly through a finer-grained matrix.

Outlier of Stoer.—The whole of the peninsula of Stoer, which forms the most westerly portion of Sutherland and covers about eight square miles, is occupied by the Torridonian formation, in

which the groups of strata represented in descending order in the following table have been recognised:—

		Thickness.
b. Applecross Group.	9. Purple and grey arkose or coarse felspathic sandstone, highly false-bedded, and including layers with scattered well-rounded pebbles of gneiss, felsite, quartzite, quartz-schists, &c. - - - - -	2500 feet.
a. Diabaig Group.	8. Bright red, more siliceous, false-bedded sandstone, with a conglomerate bed at base containing pebbles of gneiss, quartzite, quartz-schist, &c. - -	900 ,,
	7. Red mudstones, - . . - -	150 ,,
	6. Green mudstones with layers of carbonaceous shale and thin limestone band, some layers showing worm-tracks and sun-cracks, - - - -	150 ,,
	5. Hard rib of sandy calcareous mudstone, with fragments of igneous rock, - -	100 ,,
	4. Red mudstones and sandstones, . -	900 ,,
	3. Conglomerate with well-rounded pebbles of Lewisian gneiss of local origin, - -	150 ,,
	2. Red sandstone, - - - -	200 ,,
	1. Conglomerate with large well-rounded pebbles of Lewisian gneiss of local origin,	250 ,,

The prevalent dip throughout is towards the west, so that the rocks of the lower or Diabaig group, which are here peculiarly developed, occupy the base of the peninsula, while those of the Applecross group form its extremity. A line drawn from Culkein Bay on the north to Ballchladdich Bay on the south coincides with the junction-line of the two groups.

Owing to the extreme irregularity of the surface of the Lewisian Gneiss upon which the Torridonian rocks rest in this region, the sub-divisions Nos 1, 2, and 3 of the Diabaig group only appear on that part of the eastern margin of the area which lies to the north of Stoer Free Church, where they appear to fill what was a hollow in the gneiss. The conglomerate (1) is thickest about half-way between the Church and the township of Achnacarnan, and dies out both towards the north and the south before the sea is reached in either direction. This deposit is singularly coarse, its large, well-rounded pebbles consisting of the Lewisian rocks of the region, especially of acid grey gneiss, which furnishes the largest blocks and the greatest number. The reddish sandstones or arkoses of No. 2 follow the outcrop of the conglomerate, passing out to sea northwards and dying out southwards against the gneiss near the Free Church. No. 3 is a conglomerate similar to No. 1, but its pebbles are not so large. It thins towards the north, and also passes out to sea in that direction, but extends southwards as far as Rienachait (one mile north of Stoer), where it abuts against the old gneiss ridge.

The dip of these groups of strata is towards W.N.W. at about 20°. Their outcrops are shifted by a large north-east and south-west fault, which coincides with the hollow at Achnacarnan, and has a downthrow to the south-east of over 800 feet. On the south side of the ridge of gneiss shown on the map (107) the strata consist of sandstone and arkose, with a thin local breccia of gneiss fragments at the base. As all these beds dip towards the W.N.W. at angles of over 20° they must exceed a thickness of 600 feet, so that some of the lower beds may be the equivalents of Nos. 3, 2, and perhaps also of No. 1 as represented on the other side of the ridge. The conditions of deposit would thus seem to have been different on the two sides of the ridge in Torridonian time. When the junction of the Torridonian rocks with the gneiss is followed away from this ridge towards the south, the irregularity of the old gneiss surface becomes still further apparent. At Loch an Sgeirach the mudstones and sandstones of Band No. 4 are there seen to be in contact with the gneiss, while further south the presence of another old hollow is indicated by bed after bed abutting against the gneiss. The deepest point of the hollow coincides with the bend of the road south of Clachtoll, where local breccias represent Bands No. 3, 2, and 1. Bands 4, 5, 6, and 7 are most typically represented in the low cliffs on the north shore of Stoer Bay, where they follow one another in unbroken sequence towards W.N.W. with a dip of about 25°. Further north they continue to dip in the same direction but at a steeper angle of dip. No. 4 can be traced inland across the peninsula to the sea on the north-east coast, but it is interrupted by some minor faults near Totag and by the large fault already mentioned as occurring at Achnacarnan.

Band No. 5 follows the same course, but dies out before reaching the north coast. From its hardness being greater than that of the mudstones, between which it is intercalated, its outcrop, interrupted by faults, gives rise to a series of eminences appropriately called drums or ridges, such as Druim Mòr and Druim Bheag (Big and Little Drums), and Druim na Claise (Drum of the Clash or Hollow). No. 6 is well seen on the shore near a small waterfall. At about three-quarters of a mile inland from the shore openings were made on the outcrop, and the carbonaceous shales and limestones were subjected to a long search for fossils, but the only evidence of organisms met with were some obscure worm-tracks. Some of the layers are covered with sun-cracks. As these beds are traced northwards they change character by becoming split up by coarser sediments, so that they become hardly recognisable on the northern shore. Band No. 7 follows the outcrop of the underlying strata, and in this case also the mudstones are replaced by coarser sediment as they pass northwards.

The sandstones of Band No. 8, which form the uppermost zone of the Diabaig group as here developed, are hard, siliceous, and of a bright-red colour. They are well displayed round the Rudh a' Mhill Dearg (Point of the Red Hill), whence they can be traced northwards across the fields of the Clashmore township to the southern shore of Culkein Bay.

The junction of these sandstones with those of the arkoses of the Applecross group which form the rest of the peninsula can nowhere be seen, since it is concealed at the heads of Culkein and Ballchladdich Bays under beach-deposits and blown-sand, and over the intervening ground under a covering of glacial deposits. There can be little doubt, however, that the junction is a faulted one. The arkoses on the west side of the Bay of Ballchladdich are much shattered and crushed, and as the dip is towards south-east at 20° for a mile further west without any of the Diabaig beds coming up to the surface, the strata exposed in Ballchladdich Bay must lie at least 1000 feet above the base of the group. The fault must therefore be a large one, with a downthrow to the west. Along the shore beyond Raffin the arkoses roll over an anticline and continue dipping towards the west to the lighthouse. The axis of this anticline crosses the peninsula in a north-easterly direction and passes out to sea on the west side of Culkein Bay.

The north coast presents the finest and most continuous section of the rocks in the peninsula. They consist of massive bands of purplish and reddish arkose, varied only by a few intercalations of shale near Rudh' an Dunain (Point of the Hill Fort) and occasional pebbly bands, which are best seen on the Point of Stoer. From Rudh' an Dunain, where the dip is towards the west of north at angles of 5°-15°, the angle of inclination gradually increases till, near the bend in the coast-line, it reaches 50°. Further westwards it decreases, until near the Point of Stoer it becomes reversed for a short distance, so as to give rise to a shallow syncline. This structure favours the formation of cliffs. Hence on both sides of the point the finest precipices on the promontory rise from 200 to 400 feet above the surf. The "Old Man" of Stoer, which is a well-known sea stack and landmark, consists of a pile of arkoses dipping at a gentle angle seawards. Its isolation has been determined by the influence of two great systems of nearly vertical joints by which the strata are here traversed, and which have guided the sea in its destructive action on the coast.

Beinn Gharbh and Beinn Reidh.—On the south side of Loch Assynt opposite Quinag another striking outlier of the Torridon Sandstone, which rises into the ridge of Beinn Garbh, is more especially interesting to the geologist inasmuch as it shows clearly the double unconformability of the Cambrian, Torridonian, and Lewisian groups of rock. This feature is well seen from the northern margin of the lake. Standing on the roadside, the observer has the unconformable relations of the Cambrian to the Torridonian, and of the latter to the Lewisian, at once in view to the north on the slopes of Quinag above him; while looking southward across the loch he can easily trace the same two stratigraphical breaks admirably displayed on the northern slopes of Beinn Garbh. The quartzites are there seen gradually to creep over the successive beds of sandstone until they rest directly upon the Lewisian Gneiss at the foot of the hill. The sedimentary strata of this hill and its neighbour, Beinn Reidh, contain several intrusive sills of red porphyry, which are described in a later chapter, together with the other post-Cambrian igneous rocks. Intruded at a low angle between the beds of sandstone, they form conspicuous features along the steep hill-sides and to a large extent cover the flat top of Beinn Reidh.

Canisp (Plate XXXI.).—The next area of Torridonian rocks to the south forms the isolated ridge of Canisp, which, as is well shown on the map (Sheet 101), runs in the same north-westerly direction that is followed by the main geological structure-lines as well as by the other physical features of this part of the district. The ridge at its north-western end is rather less than three-quarters of a mile broad measured between the junction of the sandstones with the gneiss on the two sides, but towards the south-east it widens out to a breadth of a mile before the sandstones are overlain by the quartzite. From the summit (2779 feet) the north-western front of the ridge descends a thousand feet in three-quarters of a mile to the Torridonian base. The declivities on either flank are much steeper, so as to form precipitous cliffs.

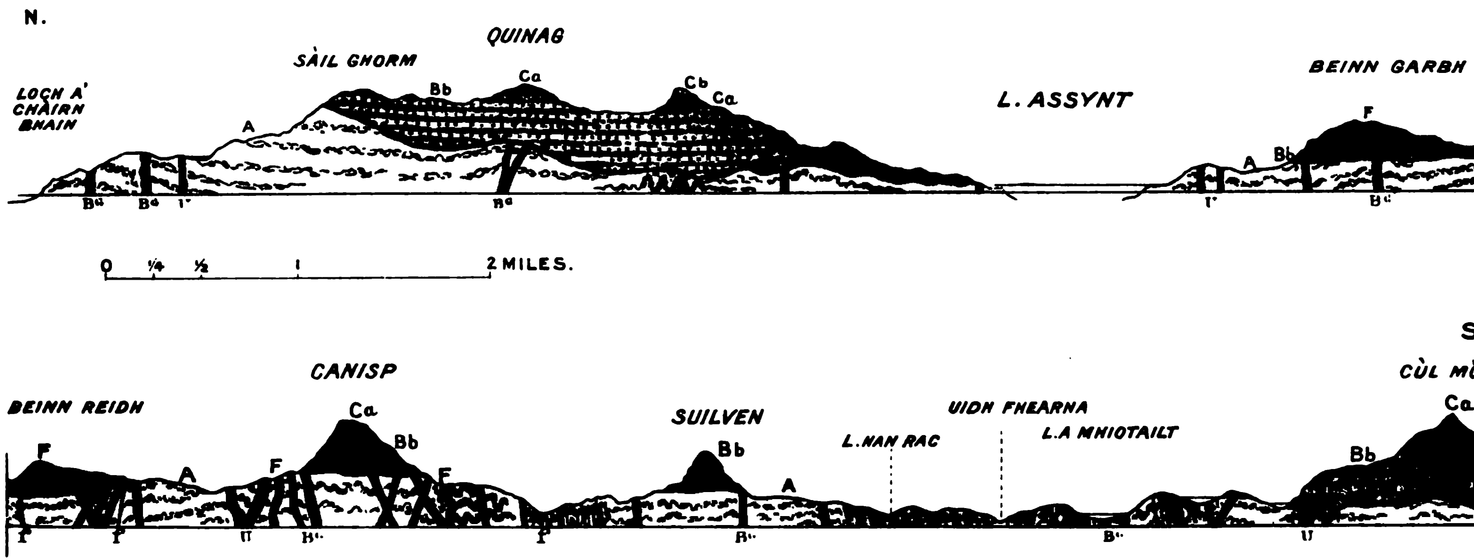
These rapid slopes belong entirely to the Torridonian escarpment, for immediately below it the gneiss plateau shows its characteristic undulating surface. In a south-easterly direction the crest of the ridge falls much more gradually across the dip slopes of the quartzite, until in a distance of three miles and a half the ground reaches the 500-feet contour-line in the valley of the River Loanan.

The highest point and eastern slope of Canisp are covered unconformably by the basal beds of the Cambrian quartzite, which form merely a cake on the upper part of the ridge. Underneath this covering purple false-bedded gritty sandstones intercalated with bands of green and purple shale rise one above another on the face of the cliffs. The steepest portions of these precipices, however, are due to successive sills of porphyry, 20 to 60 feet in thickness, which have resisted denudation better than the surrounding sediments. These sheets of intrusive rock belong to a series of igneous masses which have been injected into the various formations of this district since Cambrian time. Here they have been intercalated more or less parallel to the bedding of the strata, and have long been known to geologists by the name of "Canisp porphyry."

In Canisp the Torridonian Sandstones are inclined towards the east—that is, in the same direction as the overlying quartzite, but at an angle which does not exceed 6°, while the inclination of the Cambrian strata rises to 10° or 15°. On the south side of Canisp, a little to the north of Lochan Fada, a coarse basal conglomerate made up of locally-derived pebbles, 1-5 inches in length, rests on the eroded surface of the gneiss.

Plate XXXI.

SECTION FROM LOCH A' CHÀIRN BHAIN TO CÙL MÒR



A-*Lewisian*. Bb-*Torridonian*. Ca-*Cambrian Quartzite (Basal)*. Cb-*Cambrian Quartzite (Pipe Rock)*. F-*Porphyrite (Canisp Porphyry)* f-*Faults*.

B^a - *Basic* } *Pre-Torridon Dykes*
U - *Ultra Basic* }

Weller & Graham, Ltd Litho. London.

Suilven.—Of all the singular eminences into which the Torridon Sandstone of the North-West of Scotland has been carved by denudation, this mountain is certainly the most remarkable. It forms another of the north-west and south-east ridges above referred to. Seen from the north-west, it seems like a colossal ruined pillar with steeply-shelving sides and blunted top, rising to a height of 2399 feet above the sea and at least 1800 feet above the average level of the gneiss plateau between its base and the sea. (See Plate XXXI.) Hence it stands out from among all the cones and other shapes of the Torridonian rocks as a unique feature in the landscape of the North-West Highlands. From the south or the north it appears as a long rugged ridge with precipitous flanks and a seaboard front which descends rapidly to the gneiss plateau below.

The Torridonian outlier to which Suilven belongs stands on a long ridge of gneiss between two important valleys with chains of lakes. It shows even more impressively than Canisp the dependence of the topography upon enormous denudation guided by the tectonic arrangement of the rocks. The great lines of displacement in the gneiss and the multitude of dykes in this part of the district all run in a general north-westerly direction. The outlier follows the same trend, the Torridonian strata forming a ridge four miles and a half long and about half a mile wide towards either end, but diminishing in the middle to less than a quarter of a mile. Of this ridge Suilven forms the north-western and highest portion, where for nearly two miles the sandstone scarps rise much above the rest of the ground to the south-east. Unlike Canisp, this outlier is entirely isolated on the gneiss, and in no place has retained the cover of Cambrian quartzite.

With the exception of a thin local breccia, derived from the underlying Lewisian rocks, which is not constant, the outlier consists of the typical arkose of the Applecross group. A pile of these strata, 1600 feet thick, in nearly horizontal beds, is exposed along the cliff on the north face of Casteal Liath (Grey Castle), the western peak of Suilven. Though almost flat, the sandstones over the greater part of the outlier have a gentle south-easterly inclination at an average angle of 3°, but at the south-east end for a short distance from the margin the dip is in the opposite direction.

The surface of the gneiss upon which the strata rest is somewhat uneven. This feature is most conspicuous towards the eastern extremity of the ridge on the slopes overlooking Càm Loch (crooked lake) and Lochan Fada (long lakelet). On the ground between these lochs the escarpments representing the outcrops of massive beds of arkose are seen to abut successively against the gneiss. Near the shores of Càm Loch knobs of the gneiss protrude through the arkose and breccia, and in one case the knob is seen to be under-cut, so that the breccia actually passes underneath the gneiss. About a quarter of a mile from Càm Loch and close to the footpath leading to the ruins of the shepherd's house of Bracklach cracks in the gneiss are seen to have been filled in from above by sand and breccia of the basement beds of the outlier. Similar cracks with their infilling of Torridonian sediments may be seen on the north side of the ridge near Lochan Fada. Again, at a point in Gleannan a' Mhadaidh (Wolf's Glen), a little to the west of a loch of that name, wide cracks in the Lewisian Gneiss and in its basic dykes are filled in with breccia and arkose similar to the material which makes up the basement Torridonian rocks, while the surrounding gneiss is much reddened, weathered, and epidotised. We may, therefore, infer that the Torridonian strata have only comparatively recently been denuded from off this ground. That at the time of the deposition of the Torridon Sandstone a hollow in the gneiss lay to the north of the Suilven outlier is indicated by the Torridonian rocks passing beneath the waters of Lochan Fada, although their dip is away from the loch. The platform of old gneiss to the north on which the Torridonian outlier of Canisp rests, lies more than 600 feet higher than the base of the Torridonian rocks in Lochan Fada. Part of this difference of level may be accounted for by a fault which runs along the length of Lochan Fada and the Gleann Dorcha (dark glen), but this fault has only a throw of 300 feet down to the south-west, where it affects the outcrops of the Cambrian quartzite at a little distance to the south-east from Lochan Fada.

Not only were the Torridonian strata of the Suilven outlier laid down upon an uneven surface of gneiss, but the basement breccias contain every type of rock now to be found in the Lewisian series. It is thus clear that these ancient rocks had passed through their many vicissitudes prior to Torridonian time. Several faults cross the outlier. Some of these were of older date than the intrusion of the "Canisp porphyry," for the uppermost sill sends a tongue into the fault-fissure which cuts off the eastern peak from the rest of the mountain, while other later faults shift the continuation of the lowest sill to the north-west. One of these faults has a downthrow of 500 feet to the north-west. These igneous sills consist of the same rock as the Canisp porphyry, and they may have been continuous with those on that mountain, the connecting interval having been worn away in the stupendous denudation of this region.

Creagan Mór.—An outlier, more than a square mile in extent, lies between Càm Loch and Loch Veyatie and partakes in the general north-west, south-east trend. Its summit, like those of the loftier ridges further north, stands near its north-western front, but is only 787 feet in height above the sea. It slopes gently southward and passes under the quartzite. The Torridonian strata here consist entirely of arkose, but at their base a local breccia of gneiss fragments is occasionally seen to fill up old hollows in the gneiss. The general dip is to the south-east at 10°.

Loch Veyatie to Loch Lurgan.—We now enter upon the more continuous belt of Torridon Sandstone which spreads as a broad belt along the western margin of Ross-shire and stretches as far as the southern point of Skye. The small portion of it to be here described presents the same disposition in ridges running from north-west to south-east and having their summits near their north-western ends. Two of these ridges are comprised between the Lochs Veyatie and Lurgan. The more northerly of them forms the massive mountain Cùl Mòr (2786 feet), which, seen from the east, looks like a gigantic prostrate female figure, the head lying far to the west, the breasts formed by the Cambrian outliers on the double summit, and the trunk and limbs sloping gradually eastward to the lower ground. Its western and northern flanks rise in a long line of noble precipices. The southern ridge is much longer and more varied in outline. A depression in its centre between Loch Gainmheich and Loch Lurgan, where its level sinks to between 500 and 600 feet, separates it into two mountainous masses, Cul Beag (2523 feet) on the south-east and An Stac (Stack Polly, 2009 feet) on the north-west. Cul Beag resembles its northern neighbour in the precipitous front which it presents to the west and north. An Stac displays on its long summit ridge one of the most rugged crests anywhere to be seen in the Torridonian topography.

The rocks of which these mountains are composed belong entirely to the Applecross group, and vary little in character. The whole thickness of the strata of which Cùl Mòr is built up can be seen on the north shore of Loch Gainmheich, where more than 2000 feet of false-bedded purple grits and sandstones rise from the gneiss in a succession of huge terraced escarpments to the double summit of the mountain, each peak of which is capped with a thin cake of Cambrian quartzite. The general dip is south-easterly at angles of 6° to 8°, but in the extreme upper portion, where bands of fine-grained striped sandstone begin to make their appearance, the beds are nearly flat and the direction of dip uncertain. At the head of the grassy corrie that lies between the twin peaks a thick deposit of blown sand has been formed by the sub-aerial waste of the sandstone.

The irregularity of the surface on which the Torridonian strata were deposited is well exemplified along the northern foot of Cùl Mòr and around the shores of Loch Skinaskink and Loch Gainmheich. The coarse locally-derived breccia which here marks the base of the series runs westwards from Loch na Claise along the hollow of the Allt a' Chinn Gairbh, on the further side of which the gneiss rises in rounded hillocks 100 to 250 feet in height. The lowest Torridonian beds dip south at an angle not sufficient to carry them over the higher ground to the north, and though the breccia sometimes crosses the glen and is found on the steep slopes on the further side, it forms there only a thin skin, cemented to the surface of the gneiss by the decomposition and infiltration of certain constituents of the overlying sandstones. In this, as in other similar areas where the Torridonian rocks have been recently removed, the gneiss is generally epidotic at, and for some distance below, the surface. Outliers of breccia, in the form of thin cakes through which knobs of gneiss protrude, cover the summit of several of the rock knolls south of Loch a' Mhiotailt and along the eastern shores of Loch Skinaskink.

The unevenness of the ancient surface of gneiss is still more evident on the ground between Lochan Dearg and Loch na Doire Seirbhe, on the north side of An Stac. The base of the Torridonian is repeatedly shifted by a series of cross-faults having a downthrow to the west, so that the irregularities described in the foregoing paragraph are here repeated in many places amongst the hollows and rocky eminences that surround these lochs.

The arkose series thickens towards the south. The false-bedded grits and sandstones of Cul Beag, measured from the shore of Loch Lurgan where the base is not seen, reach a thickness of at least 2300 feet. The inclination remains steadily to south-east at an average angle of about 14°, and as the general slope of the eastern side of the mountain is about 18°, it forms very nearly a dip slope. The lowest beds at the foot of this mountain often consist of coarse pebbly grits, containing pebbles a quarter to three-quarters of an inch in length scattered irregularly through a sandy matrix. There are also intercalations of striped purple sandstone, while bands of green shale and flagstone occur at the roadside a quarter of a mile south and two miles west of the shepherd's house at Lineraineach on Loch Lurgan.

The junction of the Torridonian rocks with the overlying Cambrian quartzite is well exposed for nearly two miles along the lower course of the Allt an Liath Dhoire, immediately to the west of Drumruinie Lodge (one and a half miles south-east of Loch Lurgan). The coarse Torridonian grits and pebbly basal quartzite present at this place a deceptive appearance of conformity. Both series dip in the same south-easterly direction at angles of 15°-20°, the difference of inclination between the two being rarely more than one degree.

On the west side of Cul Beag the grits rise in a vertical escarpment several hundred feet in height, seamed by deep gullies cut by the streams along joints or lines of fault. The Torridonian rocks extend for some miles further westward through the Aird of Coigach, forming a smooth ridge mostly covered with morainic drift, but rising steeply to form the weathered serrated crest of An Stac, already quoted as an instance of a Torridonian mountain in an extreme stage of decay.

CHAPTER XVIII.

COIGACH TO LOCH MAREE.*

The district described in this Chapter includes the broad but much-indented belt of Torridon Sandstone which stretches southward from Rhu Coigach and the Loch Lurgan chain of lakes, across the mouths of the two Loch Brooms, to the line of the great depression filled by Loch Ewe in its seaward part and by Loch Maree inland. To the south of the lake-filled valley that extends from Enard Bay to Drumrunie Lodge the ground mounts up into the range of the Coigach hills, which culminate in the long ridge of Ben More (2438 feet), and presents other three summits which rise above 2000 feet. The north-west part of Coigach, including the peninsula of the Rhu More between Loch Broom and Enard Bay, is a comparatively low-lying tract traversed by the north and south valley which, with its two lakes, runs from Baden Bay to Achnahaird. The highest point of the peninsula, Meall an Fheadain (663 feet), forms part of a ridge that runs north and south in the direction of the strike of the strata.

Opposite the mouth of Loch Broom lies a little archipelago formed of Torridon Sandstone like the adjacent parts of the mainland. The most northerly group of islands, known as the Summer Isles, are a continuation of the rocks of the Rhu More, and display a rugged, rocky surface, of which most of the marked features trend with the strike of the strata, as in the peninsula to the north of them. The largest and highest islet, Tanera More, rises to a height of 406 feet.

The peninsula between Loch Broom and Little Loch Broom, which consists almost wholly of Torridon Sandstone, rises near its north-western end into the featureless mass of Beinn Ghobhlach (2082 feet). But it is to the south of Little Loch Broom that the Torridonian formation presents in this district its most imposing topography. In the Dundonnell Forest it towers into the majestic mass of An Teallach, which for height, extent, and endless variety of cliff, buttress, peak, and corrie has no rival among the north-western mountains of the Scottish Highlands.† Its

* By the late W. Gunn, with notes from C. T. Clough, L. W. Hinxman, and H. M. Cadell. The district described in this chapter is comprised within Sheets 91, 92, 100, and 101 of the Geological Survey Map.

† An Teallach, with its flanking waterfalls, was briefly described by Macculloch in his *Highlands and Western Islands of Scotland*, vol. ii., p. 311. He called it Kea Cloch. A view of a portion of the mountain as seen from the east is given in *Scenery of Scotland*, p. 225.

loftiest summit (3483 feet), called Bidein a' Ghlas Thuill, is the western culmination of its central ridge, but Sgurr Fiona to the south is 3474 (only 9 feet lower). The three great spurs of the mountain which run out to the eastward all exceed 3000 feet in height. On the same vast ridge, at a distance of three miles, Sail Mhor rises to 2508 feet.

On the south-west side of the An Teallach range the ground sinks rapidly into the long hollow filled by the Loch na Sheallag, the surface of which is only 279 feet above the level of the sea. This depression furnishes another striking instance of the coincidence of the more important topographic features with the structure of the older rocks of the district. It runs down to the sea in the usual north-westerly direction along the general trend of the tectonic lines of the old gneiss. On the southern side of this valley the Torridon Sandstone rapidly rises once more into an imposing group of mountains hardly less in altitude than their gigantic neighbours to the north—Beinn Dearg Mhor (2874) and Sgùrr Bàn (3194). On the long chain of heights that stretches southward from the head of Little Loch Broom a number of the summits are capped with outliers of quartzite-remnants left there after the prolonged post-Cambrian denudation of the region. As these cappings are white and contrast vividly with the reddish-brown colour of the sandstones below, they present not the least singular feature of the landscape in this part of the district. It seems as if the mountain-tops retained their coverings of winter snow, and where the quartzite screes have slid down the slopes below they might almost be taken for the first beginnings of glaciers of the second order.

Another of the long north-west and south-east depressions, with its chain of lakes (Lochan Fada, Dubh Loch, Fionn Loch, and others), separates the Torridonian ridge of Sgùrr Bàn from the great mass of the formation which at the head of Loch Maree sweeps up to a height of more than 3000 feet above that sheet of water and forms the imposing bulk of Slioch (3217 feet).

Three other separate areas of Torridonian rocks have here to be mentioned as coming within the district now under description—the Rudha Mor, between Gruinard Bay and the mouth of Loch Ewe, a strip of ground which stretches from Gruinard Bay to Poolewe, and another strip on the west side of Loch Ewe. The Torridonian rocks of the Rudha Mor peninsula are a continuation of those of Coigach and the Summer Isles, and display the same topographic features in coincidence with the strike of the strata. This tract, however, is varied by the occurrence in it of patches of Secondary formations. These, together with the underlying Torridonian Sandstones, are prolonged into the Isle of Ewe. The strip of these sandstones between Gruinard Bay and Loch Ewe is separated from the Rudha Mor by the Triassic and Liassic band of Aultbea and Laid. Towards its northern end it rises to a height of nearly 900 feet, but falls gradually towards the south until in the neighbourhood of Loch Ewe most of it lies below 500 feet. On the west side of Loch Ewe a low-lying strip of Torridonian ground stretches from Inverasdale in a north-westerly direction to Camstrolvaig. Nearly the whole of it lies below 300 feet, and it is abundantly strewn with lakes. Its western boundary is marked by the straight line of the great fault which has been already referred to as coincident with the hollow of Loch Maree. On the west side of this dislocation the ground rises steeply to more than 900 feet in places along the central line of the peninsula.

Torridonian Unconformability on the Lewisian Gneiss.—The present district furnishes much interesting and important evidence that the surface of Lewisian Gneiss on which the Torridon Sandstone was deposited resembled in its irregularity the gneiss ground now exposed to view. Indeed, some of its hills and valleys, after having been long buried under the overlying sandstone, have been uncovered and are still hills and valleys at the present day. In several places the nearly-level beds of the Torridon are seen to abut against the gneiss along a line which runs steeply up a hillside sometimes for a vertical height of 1000 or 2000 feet, or even more. On Slioch the ancient land surface rises up to 2200 feet above the level of Loch Maree at Fasagh. Another conspicuous example is displayed on the south side of Loch na Sheallag, where the gneiss in Beinn Dearg rises as an old hill, the summit of which is 2000 feet above the level of the loch. Beinn Dearg Bheag is connected with its loftier neighbour by a narrow and thin strip of Torridon Sandstone perched on the ridges above Loch Toll an Lochain, and is thus practically an outlier. Along the flanks of the gneiss hill the sandstones on either side in gently inclined beds overlap each other for a height of some 2000 feet. A further proof of the unconformability is furnished by patches of nearly horizontal Torridon rocks adhering to the sides of gneiss cliffs several hundred feet above their base. Again this relation of the two formations can sometimes be strikingly shown where subsequent movements have deranged their original position. Thus in some areas the Torridon Sandstone, dipping at a somewhat steep angle, strike directly at a gently-sloping surface of gneiss, as may be seen on the east side of Loch Ewe between Tuirnaig and Loch nan Uain. The line of junction between the two formations can there be followed across the strike of the Torridon Sandstone for about half a mile, and as the dip of the beds is from 20° to 25°, if they were restored to their original approximatelv horizontal position, they would be found to end off against a steep hillside for a height of as much as a thousand feet. In this and other cases no faults exist along these lines of junction, for the sandstone can be traced into little bays and around projections. At one point of this tract, where a bay of Torridon Sandstone runs up into the gneiss in a north-east direction to Loch Mhic Ille Riabhaich, no fault can be detected at the junction-line. The distance across the strike of the strata amounts to about 6600 feet, and if the average dip be taken as only 20° (though it is 25° to 30° for a considerable distance), there must be a thickness here of at least 2200 feet, which would be the height of the ancient mountain of gneiss against which the level beds of sandstone were deposited.

General Structure of the District.—All the different subdivisions of the Torridon Sandstone are well developed in this district, especially the highest known beds, of which there is a unique section at the Cailleach Head near the mouth of Little Loch Broom. The district may be conveniently sub-divided into two portions by a line drawn in nearly a S.S.W. direction from Enard Bay to Loch Maree. It will be seen from the map that this line coincides with that of the chain of gneiss inliers which, beginning at Enard Bay, is continued by those of Achiltibuie, of the islands that stretch across the entrance to Loch Broom, of the knobs near the Cailleach Head, and of Carn Dearg an Droma, till we reach the main gneiss area at Gruinard. It may be reasonably inferred that this long line of gneiss summits marks a prominent ridge of Torridonian time which might not improbably serve for a time to separate the areas of deposit on its two sides until it was submerged and buried under the Torridonian sediments. But, besides any original topographical feature which may have existed, the line of separation which has here been taken appears to be in large measure one of faulting, the effect whereof has been to throw down the strata on the west side so that the uppermost members of the Torridonian series are brought down against the basement beds which wrap round the bosses of Lewisian gneiss.

As this line of fault is such an important feature in the structure of the district, its precise course may here be traced. From Baden Bay in Coigach southwards for some distance it is concealed under the sea to the west of the Horse Island and Carn nan Sgeir. It crosses the promontory just east of the Cailleach Head, and, again passing under the sea, trends between Gruinard Island and the mainland, until it emerges again at First Coast on the south side of Gruinard Bay. Thence it can be traced by Beinn Dearg, Bad na Chailleach to Loch Thuirneag, where its throw seems to be decreasing. Everywhere along the course of this dislocation either Cambrian or Upper Torridonian strata appear on its western side, while the lowest division of the latter formation is found on the east side.

The rocks on the two sides of this line of dislocation present some characteristic differences in their topographical features and tectonic structure. While the ground on the east side rises into lofty hills composed of strata so gently inclined that their basset edges form lines of terrace along the shores, that on the west side presents no lofty prominences, and the strata often dip at steep angles and give rise at their outcrops to minor features that for the most part trend with the general strike. Another important distinction is to be found in the entire absence of the highest group of the Torridonian series in this eastern area, where the Cambrian quartzite lies everywhere unconformably upon the arkoses of the Middle or Applecross group, while the western area contains the most complete representation of the whole Torridonian formation that is to be found in Scotland.

E a s t e r n A r e a.—(1) Diabaig Group.—Beginning at the northern part of the district, we may remark that the Diabaig or lowest group of the Torridonian series is not improbably represented in Coigach, but this ground was mapped by the Geological Survey before the Torridonian sub-divisions were established elsewhere. The basement beds are varied in character, and probably do not always mark the same geological horizon. The lowest is sometimes a coarse conglomerate, sometimes a coarse red felspathic sandstone. Elsewhere fine flaggy sandstones and bands of shale or mudstone appear, which cannot be traced far.

Conglomerate and brecciated conglomerate made up mainly of gneissose fragments can be observed on the north and west sides of the gneiss inlier at Achiltibuie, and west of Achlochan (east side of Baden Bay) the basal conglomerate is of a very coarse character, consisting of large gneiss blocks. The rest of the peninsula here consists of the ordinary red flaggy false-bedded sandstones.

Grey micaceous flags of the Diabaig type intercalated with shales having a low westerly dip are exposed on the shore to the south-east of Loch Poll an Dunain, and beds of much the same character are well seen in the first stream east of Polglass (north side of Horse Sound). These flags are succeeded along the shore to the south and in the Badenscallie Burn by overlying fine and coarse red sandstones. Beyond Badenscallie the shore shows grey and purple micaceous flags succeeded by green flags capped by sandstone, and further south still, by grey flags, shales and flaggy sandstones. These flags and shales are probably a repetition of those near Polglass.

Round the bosses of gneiss near the entrance of Little Loch Broom the basal beds are in places well developed. In the bay west of Carn Dearg patches of red sandstone may be observed adhering to the cliffs of gneiss. At Annat fine red felspathic well-bedded grits and sandstone with no false bedding dip to the south-east at low angles or roll slightly. Near Badacrain (Annat Bay) rocks of much the same character appear, with occasionally a few large pebbles and ripple markings that trend north-east and south-west, together with some thin shale bands. Fine grits and hard-bedded sandstone dipping easterly are found east of Scoraig, and again on the south side of the loch from Badcaul to Badluchrach, where, however, they mostly present a westerly dip. On the south side of the entrance to this loch a band of a peculiar kind has been mapped from Stattic Point to Sron na Fàire Moire ranging nearly parallel to the coast. At first sight this rock seems igneous, but closer examination shows it to be a breccia made up of igneous fragments, principally of epidiorite, &c., evidently derived from the basic dykes associated with the gneiss, and therefore merely a variety of the basement conglomerate. The same band occurs on the north side of the loch to the west of Scoraig, where it takes the form of a dark-purple grit deeply stained with ferric oxide, and composed of angular fragments of felsite and grains of quartz and felspar.

On the south side of Gruinard Bay several detached patches or outliers of the basal Torridonian rocks may be seen. Again, between Gruinard House and Mungasdale, a number of outliers of the basal conglomerate have escaped denudation. Further west, between the Little Gruinard River and Inveriavanie River, two larger outliers of a coarse gneiss-conglomerate present a north-westerly dip. The cliff on the west side at the foot of the Inveriavanie River affords a fine section of the material. Further evidence of the former extent and subsequent denudation of the basement members of the Torridonian series is afforded nearly three miles to the south-west, where another outlier of these strata may be seen resting on the gneiss east of the outlet of Loch Fada. The long strip of Torridonian rocks east of the fault at Beinn Dearg Bad Chailleach affords good sections of the basal beds, which display regular bedding and characteristic large white quartzite pebbles.

On the southern side of Little Loch Broom much of the ground south of Badluchrach is so drift-covered that the rocks underneath are concealed. South of Durnamuck, however, numerous sections which have been laid open on the shore, and still better in the water-courses, show alternations of fine sandstone, mostly flaggy, with coarser and thicker bedded portions which pass into pebbly sandstone and then into conglomerate. The streams west of Badbea expose the characteristic red and grey flags of the Diabaig group, ripple-marked but not false-bedded, which seem to abut against a knob of gneiss. Between Lochan Gaineamhaich and Loch na Sheallag the greater part of the basal group consists of sandstones of a brighter red than the coarse arkoses which come above. In places, however, below these bright red beds, coarse pebbly sandstones and conglomerates may be seen, which appear sometimes to alternate with the brighter beds. All these strata, which are taken to represent here the Diabaig group, dip at a low angle to the eastward under the coarse grits or arkoses of An Teallach.

On the south side of Loch na Sheallag a series of hard flaggy bright-red sandstones without pebbles separates the basal shales from the purple sandstones or arkoses. Below these on Beinn Dearg black shales, about 40 feet in thickness, make their appearance, followed by blue, black, and ferruginous greywacke and sandy seams in shale, the whole succession having a thickness probably of about 250 feet. A fine section has been laid bare north of Beinn Dearg Bheag, where about 40 feet of black shale can be seen. These shales and those visible at Doire Gaineamhaich (one and a quarter miles north-east of Beinn Dearg Bheag) are full of black streaks and blotches, which are strongly suggestive of the possibility of discovering fossils in them. In a Silurian region such strata might be expected to yield lingulæ or trilobites.

It is important to note that the local base, which is always a conglomerate or breccia, may occur at any horizon for a distance of 2500 feet up in the series, according to the irregularity of the gneiss ground on which the Torridonian series was laid down.

On the southern margin of the district described in the present chapter some extremely interesting exposures have been found of the basal conglomerates and breccias and of their relations to the remarkable topographical features of the subsiding gneiss land on which they were deposited. At the back of the mountain Slioch an outlier, consisting mainly of coarse breccia, extends from near the foot of Loch Garbhaig far up the high ground to the north-west. As it ascends it divides into irregular arms which show well the steepness of the surface on which the breccia was deposited. Four other small outliers of similar rock which lie still higher up indicate how the hornblende-schist has here been encased in Torridonian sediments. Again, the patch of coarse breccia which rests on the steep hillside of hornblende-schist, on the north side of Loch Garbhaig, half a mile east of the outlet, shows clearly that its different bands have been deposited almost horizontally against a steep face of the schist. On the other side of the same hill, half a mile south-east from the foot of Lochan Fada, another outlier of breccia sends out westward an arm, at the north end of which the hornblende-schist face to which the breccia adheres is nearly vertical. Where no breccia is now left the planes of the hornblende-schist are frequently stained with hæmatite and are streaked with hæmatite veins, while the quartz veins are reddened and abundant epidotic strings have been developed, the epidote being sometimes in distinct crystals which are included within quartz crystals. Examples of these features may be found to the west, south-west, and east of the top of Beinn Lair, in one case at a height of more than 2500 feet. The general inference to which they point is that the present gneiss surface coincides in its larger features with what was the form of the ground in Torridonian time also. (Fig. 11.)

To the north-east of Beinn Lair the lofty A' Mhaighdean has preserved an outlier of breccia and grit, the most abundant pebbles in which are of the Beinn Lair type of hornblende-schists, and often 5 or 6 inches long. Yet this outlier rests directly on quartzose gneiss, hornblende-schist *in situ* being quite a mile and a half distant, though possibly at the time of the formation of the breccia hornblende-schist may have existed in mass at a nearer point. About half a mile north-west of the top of A' Mhaighdean, in a rather fine breccia, the hornblende-schist pebbles, about 1 inch in length, indicate by the direction of their inclination that they have probably come from the south-west. In the large outlier which rises on the north side of Fuar Loch Mor the breccia bands contain pebbles, one or two inches long, chiefly of the Beinn Lair type of hornblende-schist.

(2) Applecross Group.—This group as developed in the eastern area of the district now under description attains a considerable thickness and presents the characteristic features by which it is everywhere distinguished. It is usually of a purplish-red colour, but with occasional lighter-coloured bands. It is often markedly pebbly and felspathic, the felspar when newly broken being red and fresh, but weathering to a whity-brown or

rusty colour. The pebbles, mostly of vein-quartz but with a few of felsite, range up to two or three inches in length. Though sometimes scattered sparsely through the rock, they are often arranged in layers. They abound in false-bedding to such an extent that the amount of their dip is often indeterminable, but here and there thin bands of finer sandstone serve to mark the true inclination. The angle of dip of the beds is almost uniformly low, ranging between 5° and 15°, with perhaps an average of about 10°. The direction is commonly towards the south-east, though sometimes to the north of east. About An Teallach it is nearly due east. Sail Mhor, at the north-west end of the Dundonnell Forest, seems to owe its isolated position to the fact that it lies in a geological basin or syncline.

The false-bedded pebbly grits of the Ben More Coigach group of mountains dip steadily to the south-east at an average angle of 10°-15°. Some of the pebbly bands on Ben More Coigach are so coarse that the rock might be described as a conglomerate. It contains rounded and sub-angular fragments of quartz, quartzite, jasper, and chert, set in a felspathic matrix which is often slightly epidotic. A band of hard, fine-grained, bright-red or pink sandstone, resting on greenish-grey, ripple-marked flagstone, forms a low escarpment along the southern shore of Loch Lurgan west of the islands. Similar rocks can be traced along the hillside between Loch Bad a' Ghaill and Lochan Sgeireach, and also on the coast at Horse Sound, between Badenscallie and Achininver.

The bright-red rocks of Loch Lurgan recall the upper red grits of the Diabeg group, but their position at more than one horizon in the arkose group in this area shows that they are here a local development only, and lie considerably higher in the series than the red rocks of the lowermost group.

Coarse conglomerate with grit bands is seen resting on the gneiss at several places between Loch Bad a' Ghaill and Meall Leathad an Sithein, where it is cut off by a fault. A considerable amount of overlap occurs along this line, and the Torridonian strata rise rapidly from the shore of the loch and pass over the summit of a hill of gneiss more than 250 feet in height.

Owing to the unequal extent of the denudation, the visible thickness of the Applecross group in the eastern area of this district varies considerably. It is more than 2500 feet in Sail Mhor, about 2300 in Mac' us Mathair, and about 3000 in the crags of An Teallach, or more than 3000 if counted from the level of Loch na Sheallag to the summit of the mountain. Allowing for a moderate dip in the latter case, the thickness may be 4000 feet or more. On the south side of Loch Broom an estimate of the thickness in a section drawn from the sea level at Annat Bay over Beinn Ghobhlach to the summit of Beinn nam Ban (1901 feet), a distance of 4½ miles, with a fairly steady dip of 10° or more, gives between 5500 and 6000 feet. Another computation, from near Achiltibuie in Coigach over Ben More to Achendrean in Strath Kanaird, a distance of nearly 7½ miles, gives a total thickness of 6600 feet. If 600 feet be taken for the thickness here of the Diabaig group, then that of the arkose group will amount to 6000 feet. Yet, in spite of this vast depth of sediment, no trace has here been found of the highest or Altbea group. In this area the Cambrian quartzite everywhere rests on the arkoses, while only a few miles to the west, on the downthrow side of the large Coigach fault, 2000 to 3000 feet of the Altbea series are interposed between these two formations.

In concluding this account of the Torridonian groups in the eastern area of the district, reference may be made to some singular results of the weathering of these rocks. Where the pebbly sandstones decay rapidly, as in Isle Martin, the pebbles of vein-quartz, quartzite, felsite, and other materials are left behind on the surface, while the fine sand is blown or washed away. Again, the disintegration of finer sediments in the tempestuous climate of these north-western regions sometimes gives rise to effects that are usually thought in this country to be confined to our coasts. On the high plateau between the peaks of An Teallach and Mac' us Mathair to the north-west the sandstone is decomposed to great depths, and the loose sand blown about by the wind forms dunes comparable to those ordinarily seen on the sea-shore.

Western Area.—On the west side of the powerful fault that traverses this district the Diabaig group is specially characterised by the great development of its basement conglomerates and breccias. If we follow the distribution and variation of the group from south to north we find that on the north-eastern shore of Loch Maree the coarse detritus of which the lower portions of the group largely consist is well displayed to the south-east of Inveran, where coarse greenish and grey gritty sandstone passes into a conglomerate or breccia of gneiss fragments, so coarse and massive that it might be mistaken at first for gneiss itself. The red and greenish sandstones alternate occasionally, sometimes containing large pebbles and often much veined with quartz in small strings. The dip is west or north-west from 15° to 20°, and sometimes more. A specimen (3893) taken from a rock in this locality is shown by microscopical examination to be a greenish grit with epidote. East of Loch Ghiuragarstidh (two miles east of Poolewe) another breccia of gneiss fragments, which forms a marked faulted feature running north-eastwards from the loch, represents a singularly coarse aggregate. One block of gneiss in it was found to measure 14 feet in length.

Above these strata to the north of Loch Kernsary a thick series of light red and often bright red sandstones, with occasional bands of conglomerate which dip steadily to north-west, gives rise to ridges and hollows that strike to the north-east or north-north-east. Near the mouth of the River Ewe the inclination turns round towards the north-east. The upper limit of these strata is not easily determined, for it is hard to say where the regular arkoses come on. This well-bedded series of fine-grained bright red sandstones appears to belong to the Diabaig group and to correspond in great measure to what has been called the "foxy" group elsewhere, but no shales or grey flags have been met with in the area now under description. The rocks are much crushed near the line of fault which runs N.N.W. from Loch Kernsary, while along the great north-east fault, which runs parallel to the road between Inverewe and Tuirnaig, much brecciation may here and there be observed.

The second or Applecross group of the Torridonian formation in the western area of the present district is best displayed to the west of the Coigach hills in the Rudha Mor and some of the islands that stretch across to Gruinard Bay. The usual lithological features of the group are there characteristically shown. All the outermost of the Summer Isles consist of the typical coarse felspathic sandstones, except the Priest Island, of which only a small portion of the northern end belongs to this group. An interesting section is found on the west side of the Island of Glasleac Beag. A coarse sandstone, which there forms a marked feature, dips E.S.E. at 30°-40°, and has a very irregular base. It overlies and overlaps a set of grey flags (varying up to five feet in thickness) with some three or four thin shale bands, while the flags are underlain by coarse false-bedded grit. Eilean Cuir and the north-west end of Tanera Beg belong to the Applecross group. Glasleac Mor presents numerous faults and joints, with the dip in the unusual direction of west of south. Eilean Mullagrach likewise abounds in faults, and on its eastern side several sharp folds may be noticed. In the large island of Ristol, where the dip is uniformly eastward at a low angle, some of the uppermost beds of the group are visible.

On the mainland of the Rhu More the arkoses are well seen. To the east of Reiff they have been folded in an anticline which ranges about north-east, but their dip is far from regular and nowhere high, except near Faochag Bay, where, among many faults and crushes, it varies considerably, rising in some places to as much as 30°. To the east of the headland of the Rhu Coigach fine sandstones in strata from one to three feet thick lie between coarse sandstone. In the little bay west of the headland, where the dip is 15° to the south of west, red, yellowish and grey shaly mudstone appears together with some thin fine-grained sandstone. The arkoses occupy the shore east of Rhu Coigach as far as the fault which runs north from Clar Loch Mor.

The strata laid bare on the shore west of Achnahaird Bay lie on the strike of the high-dipping Altbea group to the south, but are totally unlike these beds. Consequently a fault with a north-westerly trend, as drawn on the map, must exist between them in the peat-covered ground in the centre of the peninsula. On the west side of Achnahaird Bay coarse red pebbly arkoses dip at first E.S.E., and then successively S.S.W. and S.S.E., as far as an anticline, where the dip changes to north-west at 20°, and round the west point of the bay to west at 10°-20°.

Altbea Group.—We have now reached the consideration of the highest member of the Torridonian formation, which is typically developed in the district now under description, and has received its name from the village of Altbea on Loch Ewe, near which its characteristic features can be satisfactorily studied. It rests conformably on the arkoses below, the sedimentation having been continuous from the one group into the other. But the general character of the sediments underwent a marked change at the close of the deposition of the coarse felspathic sandstones of the Applecross group. In the first place the prevailing colour of the strata is different, the Altbea group being marked by a paler and sometimes a considerably brighter red than that of the arkoses underneath. Again, the sandstones are finer in grain, frequently present the peculiar variety of curved false-bedding, and often weather into smooth or rounded forms somewhat resembling those of calcareous rocks. Bands of shale more often appear in this group than in that of the arkoses. They are most frequent and thickest among the highest members.

The most northerly place at which the base of this group has been traced is about Altandow, in the Rhu More of Coigach. In its southward progress the base line must keep to the east of Isle Ristol and west of Eilean Fada Mor, passing through the north-west part of Tanera Beag, and just touching the north end of the Priest Island. It then keeps out to sea, and first strikes the mainland on the Rudha Mor near Meallan Udrigill, whence it runs south-westwards across the peninsula, reaching the shore of Loch Ewe near Ormiscaig. It then continues southwards across the west end of Isle Ewe, but no trace of the group has been detected on the opposite side of Loch Ewe. It should here be remarked that the position of the base line here sketched was not always exactly determined in the Altbea district, as at the time the survey of that ground was made (at an earlier date than the mapping of Coigach and the Summer Isles) no subdivisions had been introduced into the maps of the tracts of Torridon Sandstone.

East of the line now traced the Altbea group occupies a strip of ground varying in width from two to four miles, and bounded on the east side by the large fault above mentioned, save where in Coigach a narrow band of Cambrian quartzite lies between it and the fault, and where from Altbea to Laid a band of Secondary rocks intervenes. The group thus forms many of the Summer Islands—Tanera More and the greater part of Tanera Beag, sgeirs lying south of these, nearly all the Priest Island and the islets stretching eastwards to Eilean Dubh, besides Gruinard Island, and most of Isle Ewe. The dip of the component strata is nearly everywhere towards the east-south-east or south-east at angles of 20° to 30°, or even sometimes 40° to 50°.

These highly-inclined sandstones have given rise to a form of surface in Coigach, the Summer Islands, and in the Rudha Mor different from the topography of the main masses of the Torridon Sandstone. No part of the ground rises to a great height or presents isolated conical hills. The distinguishing characteristic of the ground is its disposition in ridges and hollows, which have been already alluded to as coincident with the strike of the beds—that is, N.N.E. to S.S.W. The slopes of these ridges lie on their east or dip side, while the scarps and cliffs front towards the west. Priest Island, where the strata dip to S.S.E., affords a good example of this structure, many of the hollows along the strike being occupied by fresh-water lochs. Other excellent illustrations of the same feature are furnished by the smaller rocks or sgeirs, such as Sgeir nam Mult, which shows a succession of four examples. The same type of ground prevails south of Gruinard Bay, in the area to the east of the faulted Secondary rocks, though there it is much obscured by drift.

The best continuous section of the Altbea group is displayed on the southern shore of the Rhu More peninsula of Coigach opposite Dorney and Polbain, where, the width of the outcrop being two miles and the angle of dip varying from 15° to 30°, its thickness is estimated to be at least between 2000 and 3000 feet, and may possibly even amount to as much as 4000 feet. There may, however, be some repetition by faults, and the bedding in this group is so irregular and occasionally massive in character that false-bedding may have been here and there mistaken for the normal stratification. The higher beds of the Altbea group, like those exposed at the Cailleach Head, may possibly exist under a concealed space of 600 yards opposite Badentarbet. The group does not extend to the northern shore of Coigach. It is cut off by the fault at Achnahaird, to which reference has already been made.

It is on the promontory of the Cailleach Head, at the mouth of Little Loch Broom, that the thickest bands of shale in the Altbea group are to be seen. One of these bands forms a conspicuous feature along the strike at the extremity of the headland. The section here laid open reveals a continuous succession of well-bedded hard brown sandstone, with beds of green and grey micaceous shale and mudstone, the whole having a thickness of probably 1500 feet, sometimes ripple-marked and suncracked. A band of black shale shows black impressions like plants. Though these strata have been diligently and repeatedly searched for fossils, they have not yet yielded more than the obscure evidence of organic structure referred to in Chapter XVI.

The most important bands of shale which have been observed in this group as developed in other parts of the district may be here enumerated in the hope that future observers may be successful in detecting organic remains among them. Among the Summer Isles, at the east end of Tanera Beag, a band of grey shale, 10 feet thick, cannot be traced far on account of a fault which cuts it off. On the north-east side of Eilean Dubh a band of grey shale, 18 inches thick, has been noted, and flags occur on the north-west side of the same. On the south-east side of Bottle Island three or four feet of flags and grey shale may be seen. On the north-east side of Priest Island different bands of flags and shale, a few feet in thickness, have been observed in two places among the cliffs. Beds of dark grey shale are visible at low water on the eastern side of the Gruinard Island.

On the mainland of the Rudha Mor, the shore north of Laid and immediately east of the hill called Meallan Udrigill exposes some 15 feet of regularly smooth-bedded fine red sandstone, which in its lower part is so flaggy as to yield what might be called "tiles." The dip is about 12° south of east, at an angle of 40°. On this coast a beautiful example of unconformability is presented in an arch worn by the sea, wherein the sides consist of steeply-inclined Torridonian strata, while the crown is formed by gently-inclined Secondary beds.

On the south side of Gruinard Bay the Altbea group appears again to reach the mainland, but it is there so much faulted, jointed, shattered, and veined with quartz that its usual characters have been destroyed, and it cannot everywhere be satisfactorily separated from lower portions of the Torridonian series. This obscurity continues across most of the ground up to the shores of Loch Ewe, but to the north-east of Loch a' Bhaid-luachraich the strata exposed, dipping towards the south-east at high angles, appear to belong to the Altbea group.

CHAPTER XIX.

LOCH MAREE TO KISHORN,

INCLUDING TORRIDON, GAIRLOCH, APPLECROSS, CROWLIN ISLES, AND RAASAY.*

The extensive district now to be described measures about thirty-six miles from north to south, with a maximum breadth of about nineteen miles. It embraces the largest continuous area of the Torridon Sandstone, and displays that formation in its most typical forms. The denudation which further north has isolated the sandstones into numerous outliers has here also deeply trenched them and separated them into colossal groups of mountains, but without laying bare the underlying gneiss, save here and there where hills of that ancient rock have been buried under the vast mass of Torridonian sediment. It will be most convenient for purposes of description to divide the district into separate areas, and to trace the distribution and development of the rocks in each of them. These areas are (1) Loch Maree and Torridon, (2) Gairloch, (3) Applecross, (4) the adjacent Islands of Crowlin and Raasay.

(1) *Loch Maree and Torridon.*

The Torridonian formation reaches very nearly its greatest elevation in the wild mountain district that stretches southward from Loch Maree, surrounds the head of Loch Torridon, and sweeps eastwards to Strath Carron. Within this area are included, with the exception of An Teallach, the loftiest of the Torridon mountains:—Sail Mhor of Beinn Eighe (3217); Leagach (Liathach) (3456); Alligin (3232); Sgurr Ruadh (3141); Meall a' Chinn Deirg (3060); Beinn Damph (2958); and Fuar Tholl (2968); besides many other hills of lesser elevation. The topmost peaks of Sail Mhor, Leagach (Liathach), and Beinn Damph are thinly capped with Cambrian quartzite, but the great bulk of the mountain is in each case of Torridon Sandstone.

This portion of the ancient sandstone plateau affords an example of a stage of denudation intermediate between that found in the Applecross peninsula and that of the completely-

*By L. W. Hinxman, with notes from B. N. Peach, J. Horne, W. Gunn, C. T. Clough, and E. Greenly. The district described is included in Sheets 81, 82, 91, and 92 of the Geological Survey Map.

isolated cones of Sutherland and north-western Ross. Though we have not in this region to replace in imagination such masses of vanished strata as those that once connected the Sutherland peaks, it is evident even to an untrained eye that the mountains here also have been carved out of a high table-land. Each of them has a complete individuality, and stands out distinctly from its fellows. The cols between the heads of the opposing glens and corries do not, as in Applecross, form part of the unbroken plateau, but have been cut down to a considerable level below that of the summits, and separate the mountains from one another by valleys often of great depth. Thus the watershed between the Torridon and Kinlochewe River, in the great valley which separates Beinn Eighe and Leagach from the hills of Coulin and Beinn Damph, is only 343 feet above sea level, the other cols ranging from 900 to 1400 feet in height. In the high ground that overlooks Strath Carron on the west, the separation into distinct peaks is much less complete. The dominant feature of this region is a more or less continuous ridge that extends south-west from Loch Clair to Glen Kishorn, and presents a steep, scarped face to the north-west; while on the further side lofty spurs, separated by deep glens, run out at right angles with a south-east trend. As this district, however, lies within the area of disturbance, in which successive thrust masses of Cambrian as well as Torridonian strata are involved, it cannot be regarded as part of the original Torridonian plateau.

The most important features in the geological structure of this area of undisturbed Torridonian strata are the powerful north and south dislocation known as the Fasagh fault, and the great anticlinal fold trending approximately in the same direction, the two features intersecting one another on the northern slopes of Leagach.

The Fasagh fault, so-called from the place of that name on the north side of Loch Maree, where it is particularly well seen, traverses the area from the mouth of the Grudie River to the head of Loch Kishorn. Its downthrow is to the east, and from the effect produced on the Cambrian strata further north the amount of its throw must be considerably more than 1000 feet. Its course at the surface is marked by a deeply-cut feature on the face of Leagach, above the head of Loch Torridon. It here brings down the upper and middle portions of the Applecross group against strata much lower in the series, for the hard quartzose sandstones with shaly partings and red clay seams, seen at the roadside immediately west of Fasag, belong to the base of Group 2, while the red flaggy beds west of Torridon House may be regarded as the top of the Diabaig group. Another result of this fault may be seen in the absence of Cambrian strata in the west. The quartzites that cap Mullach an Rathain of Leagach and the eastern peak of Beinn Damph dip towards the sea, and but for the fault should have appeared on the higher hill-tops further west.

A line drawn southwards from Loch Bad na Sgalaig in Gairloch, across the summits of Beinn Dearg, Leagach, and Beinn Damph, and down Strath a' Bhathaich to the head of Loch Damph, marks the axis of a broad anticlinal fold in the Torridonian and Cambrian strata. West of this line the general dip is, with small local variations, steadily to the north and south of west. The anticline, well seen on the southern face of Leagach, where upwards of 3000 feet of thick-bedded purple gritty sandstones rise in an almost vertical wall above the road in Glen Torridon, crosses the crest of the mountain a little west of the quartzite-covered peak of Spidean a Choire Leith. The sandstones are here flat or nearly so, but dip away on either side to east and west at angles of 7°-10°. The small Cambrian outlier that caps the summit of Mullach an Rathain dips south-west, while the dip of the quartzites on the central and eastern peaks is to the east, showing that this fold is of post-Cambrian age. The quartzite on Mullach an Rathain rests upon several feet of green shale and red flaggy sandstone that may possibly belong to the base of the Altbea group.

(1) *Diabaig Group.*—Nearly the whole of the Loch Maree and Torridon area is covered by the thick arkoses of the Applecross group. But the lowest or Diabaig group is here typically developed on Loch Torridon. In the township of Diabaig, on the north shore of the Outer Loch, this group consists of the following succession of strata:—

Zone 3. Flaggy grits and sandstones becoming more massive at top, weathering bright red.
,, 2. Dark shales and mudstones, with thin beds of grit and flagstone and calcareous bands.
,, 3. Red flaggy grits and basal breccia.

The total thickness of the series at Lower Diabaig is about 700 feet. The breccia, composed of fragments derived from the underlying rocks, is a local base, and may occur at any horizon where higher beds overlap upon the gneiss. Both the highest and lowest zones are characterised by bright-red weathering, but are distinguished from each other by difference in grain. The grits of the upper zone pass into fine-grained sandstones, while the lower grits are invariably coarse, and often contain large scattered pebbles. The pebbles in this group, unlike those higher up in the series, seem to be largely of local derivation, and in the lowest zone are almost entirely composed of the subjacent gneiss.

An excellent section, in which the beds are well exposed throughout, is seen on the shore at Lower Diabaig, and may here be described. The gneiss rises from the shore to form the steep rocky eminence of An Torr, off the foot of which the basal conglomerate dips W.S.W. at a tolerably high angle, while small patches of conglomerate and breccia occur here and there on the steep slope above. Grey and red flagstones with scattered pebbles supervene, followed by about 400 feet of fissile grey shales and dark mudstones, alternating with thin bands of grit and compact fine-grained flagstone. Some of the fine-grained beds are highly calcareous and show the characteristic brown limestone-weathering. The dark shales are often ripple-marked and sun-cracked, and on some of the surfaces well-preserved impressions of rain drops can be seen. These facts point to shallow-water conditions, and the deposition of the sediment on a tidal shore, perhaps also to a warm and dry climate in which the shore silt dried and hardened between tides, so as to retain the markings impressed upon it. The shaly beds are succeeded by massive bright-red sandstones with shale partings, and these gradually pass up into the purple false-bedded grits of the Applecross group (II.). A westerly dip prevails throughout, the angles varying from 8° to 10°, but at the western end of the section the inclination falls rapidly until the strata are nearly flat. Good sections of the group may be seen in the stream that flows out of Loch Roag, and in the two burns that flow into the north-east corner of Loch Diabaigs Airde. Further inland to the north other good exposures of the lower series appear between Loch Roag and Loch na h'Uamhaig, where a considerable extent of ground is occupied by bright-red flaggy grits with large scattered pebbles. In several places sandstone and breccia may be seen filling up hollows and cracks in the uneven surface of the gneiss, which here rises rapidly eastwards, until the purple grits of the Applecross group, brought on by a rapid overlap, are found resting on the gneiss on the western side of Ruadh-Mheallan at a height of nearly 1700 feet.

Rocks of the Diabaig group are well displayed along the southern shore of Upper Loch Torridon, between Ob Gorm Mor and Shieldaig. The eroded surface of the gneiss on the east side of the Aird Mhor is overlain by a thin cake of coarse angular breccia containing blocks of gneiss five and six feet long. Further west along the coast, flaggy red grits and ripple-marked flagstones with a south-westerly dip crop out along the shore east of Badan Vugie. At this spot a shallow syncline brings on purple and grey shales with pebbly bands dipping east, while dip slopes of coarse conglomerate are seen resting on the gneiss at the mouth of the Balgy River. Breccia, with a westerly dip of 15°-20°, occurs again on the east side of Camas a' Chlàrsair (Bay of the Harper). The promontory between this inlet and Ob Mheallaidh (Deceitful Bay) is made up of red flaggy sandstones resting on grey flags and shales. The shores of the latter bay afford good exposures of purple fissile flagstones and greenish micaceous shales, the surfaces of the flaggy beds often showing sun-cracks and ripple-marks. The direction of the ripples, observed at Badan Vugie, runs east by north and west by south. As already referred to in Chapter XV., the base of the Torridonian series rises rapidly from the sea at Ob Mheallaidh, and passes round the northern end of Beinn Shieldaig. The arkoses of the Applecross group overlap the Diabaig strata against the steep sides of the pre-Torridonian hill until they rest on the gneiss at an elevation of over 800 feet on the north-western shoulder of the mountain above Ceann-locha.

False-bedded grits and sandstones of the Diabaig group occupy the ground on the southern shore of Loch Shieldaig and along the course of the Amhainn Dubh. They dip south-west at 10°, and rise steadily in the series, until they are cut off and brought down against the gneiss along the Inverbain River by the Applecross fault. This dislocation, which also bounds the Torridonian area for some distance north of Alligin Suas, on the opposite side of Loch Torridon, trends south-westwards across the peninsula, and throws down the Secondary rocks to the bottom of the Applecross valley. The relation of these younger strata to the Torridon grits, which rise in an escarpment nearly 1000 feet in height on the north-western side of the glen, shows that whether or not the dislocation was initiated in earlier times, it has been in operation since the Liassic period, seeing that it has displaced the Secondary strata for more than 1000 feet.

Further west, among the hollows of the old gneiss ridge which has been buried under the Torridonian formation, small areas of the Diabaig group have been laid bare, as at Ardheslaig and on the shores of Loch Creagach. The gneiss cliffs along the eastern side of that loch are covered in places with thin cakes of flaggy red grit with pebbly bands and small patches of conglomerate and breccia, some of which is extremely coarse and calcareous, its large blocks of gneiss and hornblende-rock being cemented together by strings and masses of calcite. Ripple-marked flagstones and red flaggy grits, lying nearly flat, are seen along the shore at Kenmore, and also at Camas an Eilean, where they dip north-west at 10°-15°.

On the south side of Loch Maree, where projecting portions of the ancient irregular land-surface of gneiss have been laid bare by the denudation of the overlying Torridonian sediments, the Diabaig group has been well exposed in a series of interesting sections. One of these has been cut by the River Lungard at Talladale, where, under a depth of 100 feet of hard compact brick-red grits with no pebbles, a series of black and grey shales, greywackes, reddish grits, and shales can be seen in the river-gorge to have a thickness of about 250 feet. Another fine section of black grits and dark and grey shales has been laid open in Gleann Airidh Chomhaich, one mile S.S.E. from Talladale.

The structure of the ground between Loch Maree and the hilly ground to the south-east of Strath Lungard is represented in Fig 12. Between the lake and the strath one of the ridges of the old gneiss is unconformably flanked on either side by the lowest members of the Torridonian series. Strath Lungard is seen to be an ancient depression of the surface of gneiss, in which the Diabaig group, followed by the arkoses, has been deposited. To the south-east of the glen the gneiss once more rises to the surface in another ridge, beyond which the ground mounts up into the high hills of arkose in the Kinlochewe Forest.

In the section laid open by the River Lungard, the strata of the Diabaig group are seen to have a more or less persistent dip to the south or S.S.E. at an average angle of 10°, and to be traversed by small faults. They graduate upward through the fine-grained brick-red sandstones above mentioned, which in turn pass upward into massive pebbly grits of the arkose group. The uneven floor of Lewisian gneiss, with its dykes of epidiorite and hornblende-schist, rises on the east side of the valley to a height of about 1000 feet above sea-level. The Diabaig beds can be traced round the margin of this ridge of gneiss, dipping off the old land-surface at angles from 5° to 10°.

(2) *Applecross Group.*—The great mass of arkose which forms the high mountainous country that stretches from Loch Maree to Loch Torridon, and thence southwards through the wilds of Applecross, varies but little in lithological character from one part of the area to another. The huge masses of Alligin, Beinn Dearg, and Leagach on the north, and of Beinn Damph, Beinn Shieldaig, and Beinn Bhan on the south side of Loch Torridon, are almost entirely built up of pebbly grits and coarse sandstones, often full of false bedding, and with occasional bands or seams of shale and flagstone. The general dip of these rocks is south-west or S.S.W., and the average angle of inclination 8°-12°, though in the neighbourhood of the more important faults it may rise to 25° or 30°. In the Glen Shieldaig and Applecross Forests the rocks are traversed by many narrow basalt dykes of Tertiary age, and the patches of vivid green herbage seen on the hill-side above the road in Glen Shieldaig are due to the decomposition of small sheets of augite-minette, intrusive in the sandstones. The architectural character produced by the regular parallelism and nearly horizontal stratification of the sandstones is exemplified in the mural precipices and castellated buttresses that sweep up almost from the sea-level on the north side of Upper Loch Torridon and Glen Torridon. But it

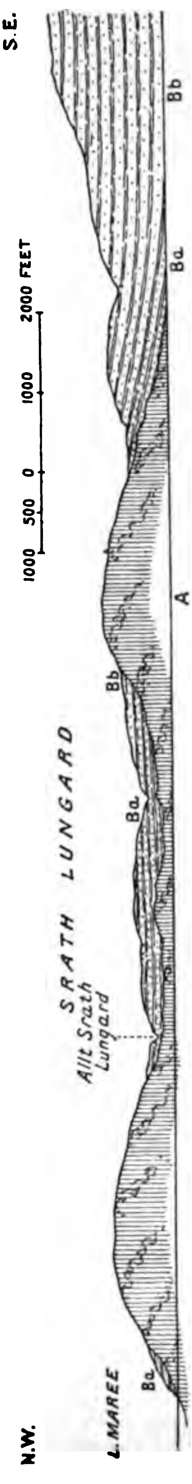


FIG. 12.—Section across Srath Lungard, showing the Torridonian Series lying upon an eroded platform of Lewisian Gneiss.
A. Lewisian Gneiss. Ba. Diabaig Group. Bb. Applecross Group.

is in Applecross that these noble features reach their highest development.

The Torridonian strata referred to in the foregoing pages lie entirely in the undisturbed region to the west of the line of complicated tectonic structure. But the area now under description includes also large tracts of the same rocks which have been displaced and modified by the post-Cambrian movements. The area of disturbance is bounded on the west by a line which runs S.S.W. from the head of Loch Maree, across Ben Eighe and the eastern shoulder of Leagach, and is continued along the southern slopes of Strath a' Bhathaich to the Kishorn River, where it is cut off by the Fasagh fault. Over the greater part of its course this line is of the nature of a thrust or reversed fault, but in the extreme north passes into a system of folds.

East of this line the relations of the Torridonian and Cambrian strata are no longer normal. A succession of thrust planes and folds, with a general N.N.E. trend, repeats the outcrops of the two formations and gives rise to a series of rapid alternations forming parallel bands, such as are seen on the map to occupy the ground between Coulin and Strath Carron.

The structure of this area is described in Chapter XXXVII.

(2) *Gairloch.*

The tract now to be described stretches from the promontory of Rudh' Re on the north to the Shieldaig Forest on the south. It is bounded on the east by the hollow of Loch Maree and the line of dislocation which runs thence north-westward to the coast about Camstrolvaig. By far the greatest portion of this large area is occupied by the Applecross arkoses. The Diabaig group, with its numerous inliers of gneiss, lies in a broad belt between the Shieldaig Forest and Loch Gairloch, and in a narrower strip along the western shore of the lower half of Loch Maree.

(1) *Diabaig Group,*—Near the base of the group, in this area as elsewhere, coarse conglomerates or breccias containing pieces of hornblende-schist and Lewisian gneiss frequently occur. No sections have been noticed in which thick coarse conglomerates overlie shales, but occasional conglomerates may be observed which seem to be as high or higher in the series than some shales or fine grits elsewhere visible. As already shown, the conglomerates or breccias must be regarded as the local base of the group, but this base varies greatly in level in adjoining localities owing to the unevenness of the underlying surface of gneiss. The breccias and conglomerates have been derived from the waste of the Lewisian gneiss and its igneous rocks. Some of the blocks are occasionally four feet long, and one example of a mass of acid gneiss four or five yards long may be seen in the breccia on the roadside east of the Loch Garbhaig Burn. Occasionally a single deposit of breccia is found to be 70 or 80 feet thick, with thin intercalated partings of sandstone.

The best sections of the Diabaig shales and grits are found at the southern end of the area in the course of the Abhuinn Braigh Horrisdale, a mile and a half south-east of Loch Bad na Sgalaig, and in the burn which flows out of Loch Garbhaig into Loch Maree. The grits are distinguished from those of the Applecross group by their finer grain, greenish-grey fracture, and bright red or orange weathering. The larger fragments in them have been derived from the Lewisian gneiss, while pieces of quartzite and quartz-felsite, such as are abundant in the overlying group, are rare. The grits are intercalated with sandy shales, most of which are dark grey, but some purple, pale-green, or red in colour. Thin lenticular laminæ of grit are abundant in the shales. Flakes of allothigenic white mica, ripple-marks, and narrow veins filled with sand that probably represent sun-cracks, are also common in the shaly beds. Repeated search has been made in these sections for organic remains, but hitherto without success. The line of division between the Diabaig and Applecross groups is not well defined in this area. The passage beds, or alternations of rocks belonging to both groups, are in some places of considerable thickness.

It has been noticed that close to certain small patches of breccia near the Gairloch Established Church the approximately vertical foliation-planes of the underlying hornblende-schist become very nearly flat, being bent over in the direction of the fall of the ground. Instances of a somewhat similar change of dip of the Lewisian rocks close to steep pre-Torridonian surfaces are not uncommon in this area, but have not been noticed away from these surfaces. It looks as if the planes in question have been bent by some agent that acted superficially with a downward motion. The two agents which first suggest themselves are soil-cap and ice. No instance of recent bending by soil-cap-motion has been observed among the Lewisian rocks, which are generally too firm and sound to be readily affected in this way. Bending of the gneiss planes, attributable to pleistocene or recent ice-action, occurs on the flat top of Beinn a Chaisgein Mòr, on the east side of the Fionn Loch.

The line separating the Diabaig from the Applecross group has been drawn at the top of the bright-red flaggy grits which overlie a series of grey and red gritty shales and flagstones, and are succeeded by grits coarser in grain and not distinguishable from typical Applecross grits. Sections of the upper beds of the group are exposed in the burn $\frac{1}{3}$-mile south-east of Badachro, on Loch Gairloch. In a burn nearly quarter of a mile west of this last-named place, the sequence of strata is as follows:—

Massive red grit, chiefly fine-grained, - - -	80 feet.
Massive fine red grit with thin dark-grey shaly partings,	110 ,,
Massive fine-grained red grit, flaggy partings, - -	32 ,,
Dark grey sandy shales, - - - - - -	10 ,,
Fine-grained red grit, - - - - - -	2 ,,
Dark greyish-green shales and bands of grey and red grit,	12 ,,
Fine red grits with inclusions of purple shale, and purple shales, - - - - - -	40 ,,

In the stream one mile north of the foot of Loch Gaineamhach the Diabaig group is well shown, and appears to exceed 500 feet in thickness.

To the north-east of Loch Gairloch, in the tract between that inlet and Loch Ewe, the Diabaig group is represented in broken tracts next to the surface of gneiss on which it rests. To the north of the road from Gairloch to Poolewe the basal conglomerates and sandstones abut nearly everywhere against the old surface of gneiss and hornblende-schist, and, as in other areas, often lie in hollows that had been eroded in these rocks before Torridonian time. A remarkable example of this kind may be seen around Loch an Eilein and Loch na Curaich, from two to three miles west of Poolewe. These lochs lie almost entirely in Torridon Sandstone, and are nearly everywhere surrounded by higher ground formed of gneiss. The hollows which they occupy must have existed before the sandstones were laid down (? rock-basins). The low dip of the beds here may be partly due to deposition on gentle slopes. East of Lochan nam Breac the conglomerate and sandstone rise into a fine escarpment, but do not form an outlier, since they are connected with the general mass.

Northward from the Gairloch Hotel, above the fine exposure of basal conglomerate there to be seen, thick red sandstones supervene, having coarse bands in places, and dipping to the west at about 10°. In Strath Bay a coarse sandstone is visible, followed to the west of the main stream by a band a few feet thick of dark-grey argillaceous sandstone, which is the only band exposed along this shore that at all resembles the typical Diabaig group. All the strata of the continuous section towards the west belong presumably to the arkose or Applecross group. In the course of the River Sand, east of the large mass of diorite that forms the hill Meall Glac na Daraich, and apparently a long way up in the arkose group, certain strata have been met with which present many of the characters of the Diabaig group. They lie, however, near the local base. Their lowest visible beds consist of alternations of massive and flaggy sandstones, dipping northwards, succeeded upwards by grey tiles and shales, massive red sandstone, and about 150 feet of grey shales passing under massive red sandstone.

In the centre of the peninsula west of Inverasdale the basal beds are well exposed about Bac and Leth-Choin. A great depth of gneiss-conglomerate with bands of red sandstone is there succeeded by coarse red sandstone with bands of conglomerate. As for more than half a mile the dip is north-westwards at 15°-20°, rising among the higher beds to 30° or more, the thickness of strata there exposed must be about 1000 feet.

The red rocks visible at the Rudh Re probably belong to the basal group, though the gneiss is nowhere visible. At the northern extremity of the peninsula the sandstone is fine-grained, well bedded, and much of it almost flaggy. The same kind of sandstone, undulating eastwards to Camas Mor, is covered unconformably by several Triassic outliers. Its successive synclines and anticlines can be followed for a long distance south of the fault which bounds the largest Secondary outlier.

(2) *Applecross Group.*—As already stated, this sub-division of the Torridonian formation covers the larger part of the district. On the north side of Loch Gairloch to the west of Strath Bay a fairly continuous section of the arkoses, with a steady dip between W.N.W. and north-west, can be followed as far as Altgreshan, a distance of six miles across the strike in a straight line. The angle of inclination varies from about 10° in the lowest beds to 15° or 20° higher up in the series. Probably this coast-line exposes not less than some 6000 or 7000 feet of the arkose group. It is true that a gap in the continuity of the shore-section occurs at Big Sand, where the Torridonian rocks are concealed under unconformable Secondary rocks, but other exposures inland along the strike and also in Longa Island opposite serve to supply the missing portions of the series. Throughout this thick succession of strata the arkose displays its usual characters. Its normal coarse pebbly texture is varied north of Port Erradale by the intercalation of bands and partings of red shale.

Further north in the peninsula the same type of strata spreads over the ground, which is for the most part covered with peat. The characteristic arkoses appear in the low-lying tract to the north-west of Inverasdale and east of Loch an Drainc. They are a continuation of the strata seen on the other side of Loch Ewe, about Mellon Charles, and at the north end of Isle of Ewe. As there is a steady easterly dip averaging about 20° across a breadth of about three miles, the thickness of rock here must amount to 5000 feet without a visible base or top.

South of Loch Gairloch, where the Applecross group is again well displayed, the best sections are to be seen on the southern coast-line of the loch between Badachro and Openham, and inland in the cliffs of Bus-bheinn and Beinn an Eoin, which rise between Loch a' Ghobhainn and Loch Maree. The grits exposed in these sections are composed of fragments of quartz—often opalescent—or of pink felspar, varying in size from a mustard-seed to a small pea. With them are large pebbles of quartzite, jasper, quartz-felsite, and other unfoliated igneous rocks.

The minor laminæ in the false-bedded bands are often curved into a vertical or reversed position, their upper edges being cut off abruptly by the overlying grit, and sometimes they assume other more complicated forms. They do not represent mere lines of staining, but differ in grain as well as in colour. A good example of this peculiar structure may be seen on the coast about a mile and a half east of the Red Point. The pebbles in the curved laminæ often lie with their long axes parallel to the sides of the laminæ, even where these are vertical.*

* This curved lamination in the Torridon Sandstone was noticed by Sir Archibald Geikie, who gave a sketch of an example of it from Gairloch in his *Textbook of Geology* (1882), p. 479.

The original inclination of the false-bedding, observed in various places in this area, seems to be generally in an easterly or south-easterly direction, as can be seen at such widely-separated localities as Sron a' Mhuilt (south side of Loch Gairloch), An Tarbh (on the coast three and a half miles south of Loch Gairloch), and the foot of the burn flowing out of Loch a' Bhaid Fhearna (three miles S.S.E. of Gairloch).

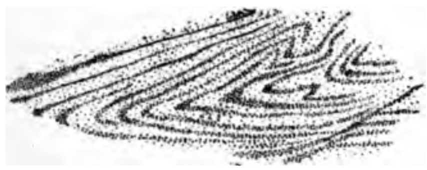


Fig. 13.—Portion of vertical face of Torridon Sandstone (Applecross Group) with laminæ in curves. Coast about a mile and a half east of the Red Point, five miles south of Loch Gairloch.

The grits of this group, here as in some other districts, are occasionally so much disintegrated as to give rise to accumulations of blown sand. This feature can be seen on the north-eastern side of Beinn Bhreac, where a considerable deposit of blown sand has been derived from the waste of the grits on the south-west side of the hill.

On the west side of Badachro Bay a series of purple grits has been laid bare, which enclose lenticles of purplish shale ranging up to three feet in length, and stripes of shale, succeeded below by fine grits, the bedding-planes of which show parallel rod-like marks, five inches long, stained with hæmatite. These strata probably lie near the base of the Applecross group. Similar grits with shale-lenticles are seen on the west side of Eilean Horrisdale, and on the coast one-third of a mile south-west of Fraoch-Eilean (south side of Loch Gairloch). On the first-named islet violent false-bedding and irregular junctions of fine and coarse-grained grits are exposed. The surfaces of the finer grits sometimes weather in irregular hollows, and show rhomboidal or polygonal forms, probably due to contraction in drying. Examples of these features are to be seen near Sron nan Gabhar and Badantional on the coast between Eilean Horrisdale and Sron a' Mhuilt (on the south side of Loch Gairloch), a mile east of Sgeir Ghlas, half a mile south-west of the top of Meall na h'Uamha (between five and six miles south of Loch Gairloch), and at various other places. Bands of clayey shale of various colours, varying from mere partings to beds one foot in thickness, are intercalated with the grits at Badantional, and at a point a mile and a half N.N.W. of the foot of Loch na h-Oidhche (about three miles south of Slattadale), near the base of the Applecross group. A bed of brick-red micaceous sandstone three feet thick occurs in the coarse grits a mile and a quarter S.S.E. of the foot of Loch a' Bhealaich (about five miles S.S.W. of Slattadale), and gives rise to a green ledge. Similar ledge-forming bands of red and yellow sandstone and shaly grit are seen on the slopes of Beinn Bhreac and Bus-bheinn.

In the account given in Chapter XVI. of the petrography of the Torridonian formation, reference was made to the scarcity or absence of pebbles of the Lewisian gneiss from all parts of the formation save the lower members, and, on the other hand, to the presence of fragments of rock for which no known source has yet been found. Percentages of the varying rocks represented among the pebbles in the Applecross group in the southern half of the Gairloch district were taken, and these are illustrated in the following table. The pebbles, one inch and upwards in length, were collected from certain spots, *a*, *b*, *c*, *d*, *e*, each about a square yard in extent, in an exposure of coarse purplish grit:—

TABLE of percentage of different rocks in the coarse grit 150 yards N.N.W. from the top of Meall na h' Uamha, 5½ miles south from Loch Gairloch.

	a.	*b.*	*c.*	*d.*	*e.*	Total.	Percentage of whole Collection.
Vein quartz, often reddened, -	14	15	18	14	9	70	40·2
Unsheared igneous rocks, chiefly quartz felsite and red felspar porphyry, - - - -	11	8	9	10	9	47	27
Quartzose Lewisian gneiss, and quartzose schist with some felspar and mica, - - - -	5	6	5	2	6	24	13·8
Jasper-like rocks, red, yellow, and black, - - - - -	4	2	4	3	5	18	10·3
Quartzite, generally of a pale red or yellow colour, - - -	4	4	4	1	2	15	8·6

Reference has already been made to the occurrence of veins of Torridonian sediment that have filled up cracks and crevices in the underlying gneiss. But in the Gairloch district the Torridonian strata themselves have been found to be traversed by veins of sandstone. Near Gairloch several "sand dykes" cut nearly vertically through Torridon grits. The trend of these dykes varies between N.N.E. and E.N.E., a direction which is also shared by some of those in the Lewisian gneiss, nearly on the strike of the most conspicuous of which these Torridonian dykes are found. Sand-dykes are seen in the coarse grit at the base of the Diabaig series in or near the burn three-quarters of a mile and again five-eighths of a mile north-west of the mouth of Lochan Druim-nà-Fearna. At the first-named place only one dyke, about eight inches thick, was observed. At the second several dykes can be seen, some of them a foot broad, and they project beyond the surface of the grit, which they cut. They contain some large pieces, which may have been derived from Torridon grit, but in most parts they are finer in grain and redder than the Torridon grit at their sides.

By far the best examples, however, are two which appear 350 yards apart, rather more than two miles south-east of the Red Point. Standing out on the coast like igneous dykes, they traverse grits which probably lie at least 3000 feet above the base of the Applecross group. One of them, about six yards wide, has distinct and straight sides from the top to the bottom of the rock-section, which is about 50 feet high, and they incline towards the south-east at about 75°. No distinct bedding can be detected in the dyke, though at one place there seems an obscure stratification which dips steeply to north-east. The grits which the dyke cuts are inclined towards north-west at about 15°, are rather coarser grained than the dyke-rock, and in some bands contain many pebbles about half an inch long. In the dyke, on the other hand, the larger pieces do not usually exceed 1-12th of an inch in length. The middle of the dyke is irregularly jointed, but the marginal portions are crossed by some rather close joints which are parallel to the sides. The other dyke, which lies further to the north-west, is also about six yards wide, and is seen from top to bottom of a cliff about 70 feet high. It is finer grained than the grits which it cuts, and it presents joints which are parallel to the side both in the marginal portions of the dyke and in the grit near it.

(3) *Applecross.*

In no part of its course along the coast of the North-West Highlands is the central division of the Torridon Sandstone more impressively developed than in the parish of Applecross. The area forms a peninsula extending from Loch Torridon to the mouth of Loch Carron, and bounded on the east by the hollow in which the road runs from Shieldaig to Loch Kishorn. It is divided into two unequal portions by the valley of the Applecross River, which coincides with one of the leading dislocations of the district. This fault is prolonged in a north-easterly direction across the water-shed, and has given rise to the valley of the Allt an t' Strathain, which descends into Loch Shieldaig. Each of these tracts has its own peculiarities of topography. That to the north stretches as a rocky expanse of Torridon Sandstone, which, rising steeply from the Applecross valley to a height of more than 2000 feet, falls gradually towards the north and west.

The southern tract presents one of the most striking scenes to be found in any portion of the region. From the alluvial flats of the Kishorn River and the northern shore of Loch Kishorn the ground rises steeply into a high plateau, of which the chief heights are Beinn Bhan (2936 feet), Sgorr-na-Caorach (2539 feet), and Meall Gorm (2325 feet). Though there is evidence to prove that even the highest summits were overtopped by the ice during the great glaciation, still the plateau is singularly bare of drift. Hence it presents in a striking form those physical features which are so characteristic of this formation. Where the streams have cut backwards into the mountainous tableland—as, for instance, Allt Coire Attadale, Allt na Fhraoich, and Allt na Chumhaing—the valleys are bounded by mural escarpments

Precipices of Torridon Sandstone. Beinn Bhan, Applecross, Ross-shire.

several hundred feet high. Where side streams have trenched these walls of sandstone, giant buttresses have been formed, as on the eastern sides of Sgorr na Caorach and Beinn Bhan. As already mentioned, these lateral spurs, intersected by deep clefts, due to lines of joint, to faults, or to the decomposition of intrusive dykes, and weathering into lofty pinnacles, represent early stages of erosion in the development of such isolated ridges of Torridon Sandstone as Stack Polly, north of Loch Broom. On the east side of Beinn Bhan, one of these ridges (An Poite) has been partially severed from the lofty plateau, with which it is now connected only by a high col. Still another familiar feature of the topography of the Torridon Sandstone, which has been alluded to in the foregoing chapters, is admirably displayed by the mountains of Applecross. Owing to the gentle inclination of the strata the hill-slopes have a terraced aspect, determined by the outcrops of harder ribs of sandstone. These regular terraced features are equally conspicuous when seen from a distance, as from the hills east of Loch Kishorn, or from the crest of the plateau looking eastwards from Creag Gorm to Carn Dearg and Sgorr na Caorach. (See Plates III. and XXXII.) Where, however, the dip of the strata is greater than the slope of the ground, as along the western portion of the Applecross peninsula between Loch Toscaig and Allt Mor, and to the north of the Applecross River, the contour is irregular. The successive outcrops of sandstone then form parallel ridges of rock with intervening hollows, which have been largely modified by glacial action.

Reference has already been made (p. 326) to the hills of gneiss which rise through the Torridon Sandstone on the south side of Loch Torridon, and on the flanks and hollows of which the lowest members of the formation are here and there exposed. These basal strata can be seen at many places along the gneiss margin between Croic Bheinn on the south and Arrin-a-chruinach on the north, and between Croic Bheinn and Inbhirban on the north-east. This area affords another striking instance of the extreme irregularity of the surface of the Lewisian gneiss upon which the Torridon sediments were deposited. Along more than two miles of the junction line northwards from Loch Gaineamhach (Sandy Loch) strata more than 1000 feet up in the Applecross group are in contact with the gneiss. Although, as already mentioned (p. 326), the Diabaig group appears near Ardheshlaig and round the shores of Loch Creagach (Craggy Loch), on the Loch Torridon side of the ridge, nevertheless further inland bed after bed of the Applecross arkoses is seen to strike at and to abut against the gneiss of the old mountain-system, the dip of these strata being persistently towards the west. This structure is illustrated in Fig. 14, from which it will be seen that the arkoses overlap the Diabaig group and, resting immediately on the gneiss, attain a great development towards the west. This section and the map (Sheet 81) likewise furnish further proof that some of the present hollows

FIG. 14.—Section from the Inner Sound of Raasay across Northern Applecross to Loch Torridon, showing the uneven surface of the Lewisian Gneiss and the strong overlap of the unconformable Torridonian Series.

A. Lewisian Gneiss. Bc. Pre-Torridonian dyke. Ba. Diabaig Group. Bb. Applecross Group. D. Basalt dykes.

on the gneiss surface are older than the time of the Torridonian sediments which were deposited in them, and have not yet been everywhere removed from them by denudation. Thus, on the eastern side of the gneiss ridge which extends from Arrin-a-chruinach southwards to Croic Bheinn, many of these ancient valleys may be seen still choked up with the angular debris of Torridonian time. Examples of them are well displayed round the shores of Loch a Coire Buidhe, in the hollows of Beinn Tire, at Ardheshlaig, and in the lower course of the Inbhirban River. It is worthy of note that the higher up the slopes of these old mountains the strata are followed the less breccia appears in them at their junction with the gneiss; indeed, it is often quite absent, the red sandstones being then found immediately resting on the older rocks. This feature is specially noticeable along the western line of contact, as may be seen between the northern bays of Lochs Gaineamhach and Ceòpach, also to the north of Loch a Bhealach (Loch of the Pass).

With the exception of these eastern tracts, where the old gneiss ridge has been once more exposed by denudation, together with its partial relics of the Diabaig group, the whole of the northern portion of Applecross is covered by the central group of the Torridon formation. This group consists here as elsewhere chiefly of reddish or purplish coarse arkose, with a few intercalations of red or green mudstone and shale. The arkoses include scattered well-rounded pebbles, which are sometimes aggregated into thin beds of conglomerate. As a rule, these pebbles rarely reach a diameter of two inches. They consist of quartzite, quartz-schist, felsitic rocks sometimes showing fluxion banding, and spherulitic structures, jasper, green slaty rock, vein-quartz, and, more rarely, fragments like the Lewisian rocks of the mainland. (See Chapter XVI. for an account of the petrography of these fragments.)

The structure of the northern part of Applecross is of the simplest kind. (See Fig. 14.) As the strata dip on the whole steadily towards the west at angles varying from 15°-25°, the thickness of the arkoses must here amount to not less than 6000 feet. The only marked feature that sometimes relieves the monotonous simplicity of the area is to be found in the occurrence, both in the gneiss and among the Torridonian rocks, of two systems of igneous dykes—an older set of mica-traps and lamprophyres with an east and west trend, and a newer series of Tertiary basalt, which runs north and south. Both systems of intrusions bleach and alter the rocks along their margins, but no other special modification was observed in this area. Besides the great fault already mentioned as traversing Applecross from north-east to south-west, and throwing down the Secondary rocks to the south with a displacement of more than 1000 feet, a number of minor faults exist, of which a considerable proportion have given rise to distinctive surface features. The rocks along their course and that of the dykes have weathered more rapidly than those at a distance from them. The chief topographical details of the ground, however, are produced by the massive beds of the arkose, which, dipping towards the coast-line, give rise to sharp escarpments facing eastwards and to long dip-slopes that sink towards the west. The coast-line, unlike much of that in the Torridon ground to the north, is comparatively low and tame. It shows two rock-shelves (*seter*) marking the 100 feet and 50 feet beaches of the west coast. All the rock features have been more or less modified by glaciation.

Though the southern division of Applecross presents a bolder and loftier series of landscapes, its geological features are on the whole a repetition of those in the northern area just described, with the omission of the gneiss protuberances and the scanty patches of the Diabaig group. The Torridon Sandstone is admirably developed, but it is represented mainly by the central group of the formation. The arkoses stretch from the Kishorn valley across the lofty plateau to the Toscaig River and Allt Mor, east of Applecross village, where finer sediments supervene, which probably belong to the highest division of the formation. The general dip of the strata is westerly or a few degrees to the north or south of that point, and the average angle varies from 10° to 12°. The sequence between Kishorn and the western shore south of Applecross village is interrupted by a few minor faults, which, however, increase in number to the south-east of Loch Toscaig, in the direction of Uags and Airidh-drishaig, where the angles vary from 15° to 20°.

The arkoses present in this area their usual aspect of massive false-bedded grits with scattered pebbles, which, in places, alternate with fine-grained false-bedded sandstones and bands of shale. The scattered pebbles in the arkoses may be seen in abundance on the hill-slope north-east of Uags—the extreme southern point of Applecross—where they consist of felsite, jasper, quartz, fine-grained purple quartzite, and other materials. The thin bands of shale occasionally associated with the group may be illustrated by an example exposed on the crest of the plateau at Creag Ghorm by the side of the road leading to Applecross, where about six feet of green shaly mudstones and dark micaceous shales are associated with false-bedded grits. Another band, about two feet thick, has been traced along the edge of the eastern escarpment of Carn Dearg and round the head of the corrie of Allt na Fhraoich that drains the col between Carn Dearg and Sgorr na Caorach.

The fine-grained sediments, which probably belong to the highest or Altbea group of the Torridon Sandstone, are well exposed on the shores of Loch Toscaig, and in the Toscaig River for about a mile to the east of the hamlet of that name; thence they extend northwards by Carn nan Uaighean (1190 feet) and An Glastulach (886 feet) towards the village of Applecross, where they are covered unconformably by Triassic and Jurassic strata. The dominant members of this series of strata are fine-grained, brick-red, false-bedded sandstones, sandy flags, and micaceous shales, which are occasionally associated with coarse grits, the whole dipping westwards at angles varying from 10° to 20°. But even to the west of these fine-grained sediments, coarse pebbly grits supervene on the shore about half a mile to the south of Milton of Applecross (where the pebbles measure about an inch across), and on Airdhubh, a promontory east of Eilean-nan-Naomh.

A section drawn from the Kishorn valley westwards by Beinn Bhan, Sgorr na Caorach, and Creag Ghorm to the margin of the Triassic rocks at Applecross, gives a thickness of about 7000 feet for the Torridon Sandstone in the southern part of the peninsula, of which the fine-grained sediments north of Loch Toscaig amount probably to about 1000 feet.

Igneous intrusions similar to those in the northern part of the area appear also in the southern portion. Thus, several basalt dykes trending N.N.E. and north-west traverse the highest part of the plateau between Meal Gorm and Beinn Bhan and the western area between Airidh-drishaig and Camasterach. A few thin sills of the same material are associated with the sandstones on the shore, about a mile and a half south of the village of Applecross. Several dykes of mica-trap and quartz-felsite also occur, as shown upon the map. The only exceptional feature among the igneous rocks of Southern Applecross is the occurrence of two small necks, probably of Tertiary age, which pierce the sandstone plateau, about the level of 1000 feet, in the valley of the River Toscaig, four miles S.S.E. of Applecross village.

Southern Applecross lies between two powerful lines of dislocation. Its north-western margin is defined by the great fault already mentioned as continuous across the peninsula to Loch Shieldaig. On its south-eastern side also it is bounded by another important line of fracture, which runs along the north-western side of Loch Kishorn and inland up the Kishorn valley. Besides these dominant dislocations various faults are traceable through the area, but owing to the uniform character of the strata it is difficult to estimate the amount of their displacement. Along the south shore, near Airidh-drishaig, branches of the great Kishorn fault, with a downthrow to the south-east, have been traced for some distance; one strikes the shore about a mile east of Airidh-drishaig, and can be followed westwards by Loch Airidh Alasdair to the coast-line north of Uags, while another occurs between Airidh-drishaig and Uags.

(4) *The Crowlin Isles.*

This little group of three islands lies a mile and a half off the south-west point of Applecross. Their combined area amounts to a little more than a square mile. They are formed of a series of hard sandstones and shales belonging to the uppermost or Altbea group of the Torridon formation, traversed by a network of later igneous intrusions chiefly in the form of basalt dykes of Tertiary age. The sandstones are reddish and grey in colour, fine-grained, compact, and hard in texture. In composition they are fine-grained arkoses, in which the felspar grains are remarkably fresh. They are divided into massive beds from two or three feet up even to twenty feet in thickness. Their finer lamination, indicating false-bedding, affords a good instance of the complicated structure already referred to, as it is singularly convoluted. These massive beds may succeed each other without any parting of other material, but a thin layer of green, red, or grey micaceous flagstone or shale not infrequently intervenes between them. Such layers of shale occasionally reach a thickness of from 14-20 feet, and they here and there show evidence of having been locally eroded before the deposition of the overlying sandstone. It is not uncommon, therefore, to find more or less rounded galls of shale in the sandstones. As the dip of the strata through the islands is towards the N.N.W. at an average angle of about 15°, the thickness of the strata here exposed must amount to above 2000 feet.

The sandstones are much affected by two systems of joints which run, approximately, the one set N.N.W. and S.S.E. and the other east and west. Some of these joints are accompanied by faults, none of which, however, appear to be of much importance, except one, which, running near to and parallel with the southern shore of Eilean Mór, is in all probability the extension of a fault on the opposite mainland, already alluded to as a branch of the great Kishorn fault. The fault on Eilean Mór is accompanied by several minor dislocations, which have given rise to much brecciation of the strata along their course. The rocks are here traversed by a network of joints and smaller faults, many of which have served as fissures for the uprise of igneous material now found in the form of dykes. Two sets of such intrusions can be distinguished. On the east shore of Eilean Mór, immediately to the east of the only dwelling-house on the island, an east and west dyke of pink quartz-felsite is seen to be cut by a north and south dyke of basalt. The former probably belongs to the older series found in Applecross, of which the age is doubtful; but the basalt dyke is no doubt one of the abundant Tertiary series. The Torridonian rocks are much bleached, hardened, and even vitrified in places where in contact with these basalt dykes. The joints, faults, and dykes give rise to narrow gullies around the coast and to trench-like hollows across the interior of the islands. The contours of all the islands have been smoothed and rounded by glaciation, and raised beaches are found at the heads of all the little creeks and inlets.

(5) *Raasay.*

The Torridonian strata in this island occupy a small area south of Manish Point, about six square miles in extent, lying between the Lewisian gneiss of the extreme northern part of the island and the Jurassic tract of the south. They likewise form the Eilean Fladday and the islet of Griana-sgeir. In general character they agree with their equivalents on the mainland. They include portions of the two lowest groups of the formation.

The Diabaig group is well developed along the eastern margin of the area, especially as regards the bright-red grits which form its upper portion. The dark flags and shales are well exposed on the shore at Brochel Castle and along the east side of Eilean Fladday. At the last-named locality they contain a few thin bands of calcareous sandstone, like that seen at Lower Diabaig on Loch Torridon.

The sequence of the strata at Brochel is as follows:—

	Feet.
Jointed grey micaceous shales, with thin bands of grey sandstone and coarse pebbly grit, - - - - -	150
Massive false-bedded bright red sandstone, with shale bands, -	about 200
Alternations of bright red sandstones and ripple-marked grey and red flaggy shales, - - - - - -	
Fine-grained red and grey sandstones, sometimes with scattered pebbles, and intercalations of grey shales, - - -	
Bright red flaggy sandstone and more massive sandstone, with occasional thin bands of shale, - - - - -	about 700

The total thickness of the series here is not less than 1000 feet. It will be noticed that the rocks in this section differ from those described at Diabaig in the greater proportion of micaceous sediments, and the absence of calcareous beds. The strata are inclined to W.S.W. at an average angle of 15°. The red grits are also well seen along the cliffs on the south side of Loch Arnish, where they dip west and W.N.W. at 15°-20°.

The basement breccia is not present in the Brochel section, but is seen clinging to the surface of the gneiss near Lochan Uachdair, along the shore of Loch Arnish, and on the east side of Caol Fladda, opposite Eilean Fladday. The dark-blue and grey flagstones of Fladday, though not cleaved, but much jointed, were formerly worked as an inferior kind of roofing slate.

The rest of the Torridonian area of the island is occupied by the false-bedded red and purple grits and sandstones of the Applecross group. They are sometimes pebbly, and contain occasional thin bands of red shale and flagstone, but as a whole vary but little in character. They dip steadily in a general westerly direction at an average angle considerably higher than that generally observed on the mainland, and ranging from 18° to 23°. They are traversed by numerous N.N.W. basalt dykes, probably of Tertiary age, which, as in Applecross, have altered and bleached the sandstone, in several instances, to a distance of more than 20 feet from the edge of the dyke. Where the igneous material, as often happens, has weathered out, it has left a narrow gully between two vertical walls of hardened whitish-grey sandstone. Reference may also be made to two neck-like masses of breccia, composed of fragments of unaltered grit and sandstone, cemented together in one case with calcite. The largest of these forms the picturesque crag on which the ruined castle of Brochel stands; the other lies a mile inland, near the west side of Lochan Uachdair. Both are probably of volcanic origin, and, like the two necks in Southern Applecross, may be part of the great volcanic series so largely developed in the neighbouring Island of Skye.

CHAPTER XX.

KISHORN TO LOCH ALSH.*

Between the Kishorn valley and Loch Alsh a considerable area of Torridon Sandstone is associated with the displaced masses that overlie the Kishorn thrust-plane. Throughout this district, with the exception of a strip of ground, about half a mile broad, extending along the shore between the mouth of Loch Carron and the Kyle of Loch Alsh, the strata are inverted. Though over much of this district, in spite of the great displacement which the Torridonian strata have undergone, they display a marked absence of schistosity, they have nevertheless been indurated, bleached, and, as shown in Chapter XVI., present characters in some places approaching those of true schists. In the tract north of Loch Carron and for three miles to the south of that sea-loch, as far as Gleannan Dorch, the basal beds of the Torridon Sandstone pass, with an inverted easterly dip, underneath the overlying Lewisian gneiss.

The Diabaig and Applecross groups of the Torridonian formation are both represented in this district, but the Altbea series has not been detected.

(1) *Diabaig Group.*—This division presents a strikingly different character here from that which it displays in the districts further north, which have been described in the foregoing chapters. In particular, it undergoes an extraordinary development both in thickness and in variety of sediment as it is traced towards the south-west, attaining its maximum in Skye. Its sub-divisions have been mapped in detail in that island, and having been first established there have subsequently been identified and followed north-eastwards on the mainland. But they rapidly diminish in thickness in that direction, until beyond Kishorn they are abruptly cut off by the Kishorn and Glen Logan thrust-plane. Adopting the classification established in Skye, we find the group in the present district to consist of the following sub-divisions in descending order:—

Diabaig Group.
- (*d*) Grey sandy shales and fine-grained sandstones with massive grey and green grits; thickness 2,700 feet (Kinloch Beds).
- (*c*) Fine-grained grey and green grits, sandstones, and flags; thickness 1,200 feet (Beinn na Seamraig grits).
- (*b*) Grey, blue, and black shales, with calcareous bands and grits sometimes calcareous; thickness 500 feet (Loch na Dal Beds).
- (*a*) Green epidotic grits with a conglomerate bed at the base, locally developed; thickness 60 feet.

* By B. N. Peach and J. Horne. The area described is comprised in Sheets 71 and 81 of the Geological Survey Map.

a. Epidotic Grits.—The conglomerate, which is locally developed at the base of this sub-division, is best seen at Fernaig, by the roadside leading from Stromeferry to Plockton (Sheet 71), where the basal beds of the Torridon Sandstone dip eastwards at angles from 18° to 20°, and pass underneath deformed Lewisian gneiss. The conglomerate, from 15 to 20 feet thick, and the epidotic grits form a prominent ledge round the face of the crag to the south. The matrix, in which lie pebbles of various types of epidotic gneiss (Lewisian), from two to twelve inches across, consists of green epidotic grit. Perhaps its most characteristic feature is the abundance of well-rounded pebbles of vein-quartz, usually stained purple. The matrix here shows marked flaser structure, and the gneiss-pebbles are sometimes flattened, elongated, and under the microscope show remarkable cataclastic structures. The conglomerate is again exposed near the crest of the prominent crag south of Fernaig, at a point about a mile due east of the mansion-house of Duncraig.

The epidotic grits, which are charged with epidote and chlorite, show on the weathered surface numerous grains of blue quartz and epidotised felspar. Under the microscope the larger grains, specially of quartz, are granulitised, and the matrix often forms a granulitic mosaic, rich in epidote and chlorite. This band of green epidotic grits can be traced continuously round the crag from Fernaig to the valley of the Gleannan Dorch, where they are truncated by a thrust to be referred to in the sequel. Northwards, the grits again appear at the foot of the great crag that bounds the 100-feet beach near Port-a-Chuilinn. On the north side of Loch Carron (Sheet 81) the characteristic features of these grits are well displayed on the shore section three-quarters of a mile west of North Strome Pier, where they are about 20 feet thick, and dip east below deformed Lewisian gneiss. Here the local basal conglomerate is absent, but no apparent plane of disruption can be detected. From the shore of Loch Carron the zone can be traced round the west slope of Bad a' Chreamha, but seems to disappear in a northerly direction; for, on the west face of An Sgorr, two miles and a half north of Stromeferry, the grey flags and dark shales of the Loch na Dal sub-division are in contact with the overlying gneiss. In Glenmore, about two miles east of Courthill House, Kishorn, a small exposure of epidotic grit is visible at the roadside, where the boundary line between the Torridon Sandstone and the overlying Lewisian gneiss is shifted by a normal fault. Northwards, the dark shales (Loch na Dal) are in contact with the Lewisian gneiss, and at Cearcall Dubh a local conglomerate appears in that position, the epidotic grits and Loch na Dal shales both being absent. These features evidently indicate the unevenness of the surface of gneiss on which the Torridonian sediments were laid down and the overlap of successive horizons against that ancient platform.

b. Loch na Dal Shales.—This sub-division consists of grey, blue, and dark striped shales, flags and calcareous bands, [illegible] and pebbly grits. [illegible] of these strata is the occurrence of [illegible] in the finer sediments. [illegible] effervesce freely with acid, [illegible] with a curious surface. The [illegible]. Further, the grits show [illegible] grains have been granulitised, [illegible] peripheral granulitisation. [illegible] have been developed [illegible] which these rocks have [illegible] which placed them [illegible].

[illegible] belt to the west of the [illegible]. Excellent exposures of [illegible] of a mile west of [illegible] a' Chreamha, and An [illegible]. South of Loch Carron they are [illegible] beach at Port-a-[illegible] they appear on the roadside, and [illegible] great crag east of Duncraig [illegible], they are truncated [illegible]. Along this line they have a persistent [illegible] underneath the epidotic grits, [illegible] succeeding group.

[illegible] Grits.—These consist of [illegible] of fine flaggy sand-[illegible] lines of heavy [illegible] phyllites some-[illegible]. The grits contain quartz, microcline, [illegible] granulitic, and con-[illegible] traversed by [illegible] quartz and vermicular [illegible].

[illegible] Dorch, this sub-[illegible] a mile broad to [illegible]. Perhaps one of the [illegible] south of Loch [illegible] Duncraig and Fernaig. South [illegible] is overridden by highly [illegible] the two being a well-[illegible]. The [illegible] structure of this region [illegible] Part IV., Sec. ii., i. The [illegible] Balmacara Hotel and on the shore [illegible] are truncated by a thrust-[illegible]. North of Loch Carron [illegible] Loch Reraig, and extend north-[illegible] east of Kishorn.

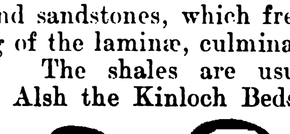
[illegible]—The prominent feature of this [illegible] of zones of grey sandy [illegible]—for example, to the east [illegible] of Loch [illegible]—have been quarried for slates.

These shales are associated with fine-grained green and grey sandstones and flags and massive grits, which, with their included quartz and felspar fragments, resemble arkoses of the Applecross group. In places along their outcrop the grits are markedly schistose, as, for instance, near Duncraig, where they contain clastic grains of quartz, microcline and oligoclase lying in a micro-crystalline matrix of sericite and chlorite, showing flaser structure. This matrix is largely of secondary origin. Indeed, over a large part of the area occupied by these grits they furnish remarkable evidence of the deformation which they have undergone.

Though shales occur at intervals throughout this sub-division, they are specially developed on two horizons—one near the top and the other near the base. The higher belt, which, as the strata are here inverted, is the more westerly of the two, is well exposed on the shore about half a mile east of Kyle of Lochalsh (Sheet 71), where the shales alternate with fine-grained green sandstone. The same strata occur at intervals eastwards as far as the Bay of Scalpaidh, presenting an easterly dip at angles ranging from 70° at their western limit to 20° on the east. They are traceable northwards by Loch Scalpaidh to Allt Dhuirinish, where they are worked for roofing slate, to the shore of Loch Carron between Duncraig and Plockton. They reappear on the north side of Loch Carron in a small bay one mile west of the head of Loch Reraig, and they cross the peninsula to the shore of Loch Kishorn near the pier at Achintraid.

The dark blue and grey slates and flags near the base of the Kinloch Beds are well exposed on the shore on the west side of Balmacarra Bay, where they dip a few degrees to the south of east at angles varying from 15° to 23°. They likewise form the hill-slope west of Balmacarra House. They are visible further east in the lower part of Balmacarra Burn, their occurrence there being due to a low arch of the inverted strata. (Part IV., Chap. XXXVIII.) Northwards they are traceable by Carn Thollaid, the west end of Loch Achaidh na h-Ithinnich and the east side of Loch Lundie, to the south shore of Loch Carron, one mile east of Plockton. On the north side of that fjord shales, probably on the same horizon, appear on the hill north of the head of Loch Reraig, and by the footpath leading to Achintraid.

The pebbly grits and fine-grained sandstones lying between the upper and lower shale-zones of the Kinloch sub-division are well seen on the north shore of Loch Alsh between the Bay of Scalpaidh and Balmacarra, where they have an easterly dip at angles varying from 15° to 25°. Some of the more massive fine-grained sandstones display the contorted bedding so characteristic of the members of the Applecross group. Bands of shale from three to four feet thick are here intercalated with the grits and sandstones, which frequently show puckering and overfolding of the laminæ, culminating in small reversed faults. (Fig. 15.) The shales are usually cleaved. Northwards from Loch Alsh the Kinloch Beds are well seen on the rocky



hills north and south of Palascaig, where the more massive bands give rise to prominent escarpments. They form the wooded hills south of Duncraig, below which they appear on the shore, while north of Loch Carron they are seen west of Loch Reraig and extend northwards to Achintraid.

FIG. 15.—Cleaved Shale with seam of Grit (3 inches thick), showing overfolding and reversed faults, on shore 470 yards east of Colonel Murchison's Monument, Loch Alsh.

(2) **Applecross Group.**—The massive sandstones and grits so characteristic of this group further north are here, as a rule, finer grained than in the typical Loch Torridon area. In places, however—as, for instance, a quarter of a mile north from Erbusaig and near Plockton—they are pebbly, and contain fragments of microcline and pink felsite. Though now usually grey or green in colour, it is probable that their original tint may have been purple, for in some places the latter is met with, and in others they have a blotched appearance. Induration and cleavage are common among them; indeed, in some of the railway cuttings near Erbusaig the sandstones have been so hardened as to present the characters of quartzites.

Lines and thin bands of heavy minerals—magnetite and zircon—are intercalated in some of the beds of arkose, as, for instance, in the Plock of Kyle, a quarter of a mile west of Kyle Inn, at the roadside a little north of Duirinish Bridge, and at several places on Coir à Mhuilt, half a mile S.S.W. of Duirinish. In some instances the bands containing these heavy minerals vary from two to ten inches in thickness.

The members of this group contain microcline, oligoclase, quartz, and scattered flakes of white mica. From the microscopic examination it appears that the deformation of the constituents decreases in a westward direction. At Plockton the proofs of strain phenomena in the grits are more marked, and there is more secondary crypto-crystalline matter in the matrix than in specimens taken from a locality one mile further west. (See Chapter XVI.)

The arkoses of the Applecross group between Loch Alsh and Loch Carron form a belt upwards of a mile in width along the western seaboard from Kyle Inn north by Duirinish to Plockton. Over the greater part of this area their dip is easterly and inverted. Reference will be made in the sequel to the north and south axial line, to the west of which the inversion ceases. (Chapter XXXVIII.)

To the east of the area of Torridon Sandstone described in this chapter, between Loch Carron and Loch Alsh, minor infolds of the formation have been caught in among the masses of deformed

Lewisian gneiss. The strata so included comprise the basal conglomerate, the epidotic grits, the Loch na Dal shales, and perhaps some of the Beinn na Seamraig grits, all showing traces of deformation like those above noticed as observable between Fernaig and the Kyle of Lochalsh.

CHAPTER XXI.

ISLE OF SKYE.*

In Skye the south-eastern peninsula, including the parish of Sleat and the east end of Strath, is chiefly composed of Torridonian rocks. Two or three miles south of Kyleakin these rocks rise into the mountains of Sgurr na Coinnich (2401 feet) and Beinn na Caillich (2396 feet), but the hills become lower in a south-westerly direction, and beyond Loch na Dal nowhere exceed 1000 feet in height. In the northern part of the peninsula the elevation also decreases rapidly towards the north-west, and low dreary peat-covered tracts cover the area between Loch Eishort and Kyleakin. On the mainland of Inverness-shire, on the east side of the strait of Kyle Rhea, a narrow strip of Torridonian rocks may be conveniently described with those of Sleat.

On the flanks of Ben Suardal, in the parish of Strath, a small Torridonian area is separated from that to the east by a narrow band of Mesozoic rocks. North-west and west of that hill various small areas of Torridon Sandstone have been mapped. One of these lies to the north-east and east of Beinn na Caillich, west of Broadford, between Coire-chat-achan and the Kyle of Scalpay, and the rocks reappear in Scalpay Island. A little further to the north-west another strip of the formation, from half to a third of a mile wide, and more than two miles long, appears on the coast east of Loch Sligachan. A third narrow strip, never more than 200 yards wide, runs for three miles along the coast of Skye, from the middle of the Sound of Soay towards the head of Loch Scavaig.

It is certain that nearly all the Skye Torridonian rocks, and also those east of the Kyle Rhea, have been thrust forward from the south-east during the great post-Cambrian movements. This displacement is well seen near Ord, on Ben Suardal, and at Coire-chat-achan. But, as a rule, the rocks in this district have not suffered appreciable deformation or alteration, and they can be separated into various stratigraphical horizons, most of which, as stated in the last chapter, are more fully developed here than in any other part of the North-West Highlands.

* By C. T. Clough, with notes by A. Harker. The ground described in this chapter is comprised within Sheets 61, 70, and 71 of the Geological Survey Map of Scotland.

Arranged in descending order, the Torridonian formation in Skye comprises the following sub-divisions of strata:—

(2) Applecross Group.—Red and chocolate arkoses with pebbles of quartzite, felsite, jasper, pegmatite, and other rocks.

(1) Diabaig Group.—(*d*) Kinloch Beds.—A series of dark grey sandy shales and fine-grained grey and buff grits with thin calcareous lenticles.

Do. (*c*) Beinn na Seamraig Grits.—Fine-grained buff or grey-green grits with some bands of grey sandy shale.

Do. (*b*) Loch na Dal Beds.—Dark grey, gritty or sandy shales with fine-grained buff grits and small calcareous lenticles.

Do. (*a*) Epidotic Grits and Conglomerates.—Beds with abundant pebbles of epidote and epidotized felspar. The finer bands show a greenish matrix. Occasional bands of purple and green shale.

The four lower sub-divisions represent in an enormously expanded form the Diabaig group of the region to the north. In Skye they occupy collectively an area about twice as large as that covered in this island by the Applecross group. The boundaries between the different divisions, though not sharp, are yet generally sufficiently developed to allow of the detection and tracing of large faults. The three upper members of the Diabaig group have many characters in common. The grits are often excessively false-bedded, and, as in those of the Applecross group, the minor laminæ within certain beds are often arranged in sharp curves, though the tops and bottoms of these beds have a uniform slope. Many of the finer grits in each division are characterised by the presence of small spots, the size of a pea or less, which are usually paler than the rest of the rock. They seem to be due to a peculiar condition of the interstitial matter, and they were no doubt in existence prior to the post-Cambrian thrusts, for in several places they have been elongated in a parallel direction along the cleavage planes. This feature may be seen two-thirds of a mile S.S.W. of Sgurr na Coinnich. A few of the coarser grits are red in consequence of the number of clastic grains of red felspar, but generally white felspar preponderates.

A traverse of the district in a south-easterly direction from Broadford Bay to the Sound of Sleat at Ardnameacan shows the several sub-divisions in their simplest relations. First comes the Applecross group, followed by the different members of the Diabaig group, in normal stratigraphical order. A considerable resemblance may be noted between the Kinloch and the Loch na Dal beds, but the other three divisions are so different from one another in lithological character that the Kinloch beds and the Loch na Dal beds cannot be regarded as repetitions of one series, with the Beinn na Seamraig grits lying in a fold between them. The great apparent thicknesses of the three upper sub-divisions do not seem due to repetition by thrusts and folds. There are no indications of thrusts or isoclinal folds, and very little cleavage can be detected along the parts of the traverse which these divisions occupy. The dip of the whole formation is continuously north-westwards—a direction opposite to that of the usual inclination of the thrusts and isoclinal folds of post-Cambrian age. It does not seem likely that the strata can once have had a general south-easterly dip, together with a set of obscure isoclinal folds and thrusts, and that these structures have been subsequently bent so as to be inclined towards north-west. Had this reversal taken place the cleavage-planes would also have dipped north-west, for it is a rule that when these planes are developed they lie parallel to the axial planes of the folds of the rocks in which they occur. But, as a fact, these planes, where seen along or near the line of traverse, always dip south-east. In some parts of the Applecross group the dip in a north-west direction has been increased in amount since Mesozoic times, but this increase has not made the cleavage dip north-west.

The general strike of all the Torridonian rocks in Skye is north-east and south-west. Those which lie furthest south-east show stronger indications of dynamo-metamorphism—more cleavage or foliation, more elongation of particles, more tendency to granulitisation in the matrix—than the rocks which lie to the north-west. Further, as they are followed south-westwards from Kyle Akin towards Loch an Eilean, in Strath, or Isle Ornsay, the metamorphism gradually decreases in strength.

The Torridonian rocks in the parts of Skye north-west or west of Strath Suardal, and in the Island of Scalpay, are much mixed with igneous rock, and it is not certain to what horizon some of them belong, or to what extent they have been affected by thrusting. These rocks will, therefore, not be dealt with in the descriptions of the several Torridonian divisions which are to follow in this chapter. A few facts relating to them may, however, be stated here.

The different patches of Torridonian rock which occur in the part of Skye between Coire-chat-achan and the Kyle of Scalpay are outliers above the Ben Suardal thrust, and they overlie Cambrian limestones. In all these outliers the rock is less felspathic and more siliceous than the usual type of Applecross grit. It is a close-grained quartzose grit, passing locally into a quartzite with cementation by silica. In the Torridonian strip east of Loch Sligachan, the lowest rocks, which are at the west end, resemble the common Applecross type. They consist of red and grey sandstones and grits, containing a considerable amount of felspar, and having pebbly bands on some horizons. Over these, in the eastern part of the area, come less felspathic and more quartzose fine-grained grey rocks, which often weather with a pink colour.

The general dip of the Torridonian rocks on the Skye shore near the Island of Soay is north-west at low angles. The lower part consists of fine-grained sandstones with some flaggy and shaly beds weathering red, pink, or grey. These are overlain by less fine-grained and pinker sandstones, with some conglomeratic bands, and then by pebbly grits, weathering pale-grey or white.

The Torridonian beds in the Island of Scalpay admit of division into two members. The highest and principal member composes most of the north-eastern and central part of the island, and also extends nearly to Rudha Aosail Sligeach. It consists chiefly of coarse felspathic sandstones, weathering reddish, often false-bedded, and with pebbly seams and beds throughout. Its thickness may be as much as 4750 feet. Below this comes finer sandstone, also felspathic, never pebbly, and this passes down through intermediate beds, which are often laminated and flaggy, into close-grained quartzose grits with little or no felspar, and of a grey, greenish-grey, or white colour. The thickness of the lower member appears to be about 1300 feet.

(1) *Diabaig Group.*—This lowest member of the Torridonian formation, which, in the Loch Carron and Loch Alsh district, assumes a different character from that of the same group further to the north, crosses into Skye and attains there its greatest development. As shown in the foregoing table, four distinct assemblages of strata can be recognised in it.

a. Epidotic Grits and Conglomerates.—This sub-division between Kyle Rhea and Loch na Dal occurs in four detached areas, none of which is as much as half a mile broad from north-west to south-east. Three of them lie near together, and form an almost continuous exposure from Port Aslaig to within half a mile of Ardnameacan. The most north-westerly area touches the coast on both sides of Dun Ruaige. In the southern part of Sleat other four or five small detached areas have been noticed. Even the largest of these, which has its approximate centre about half a mile south-west of the outlet of Loch a' Ghlinne (four miles and a half N.N.E. of Point of Sleat), does not much exceed 20 acres. The rocks in the areas adjoining the Sound of Skye are well exposed in coast-sections, and those in the southern part of Sleat are also for the most part bare and craggy.

In no unthrust area of the Torridon Sandstone do we know of rocks quite like what those under description may be supposed to have been in their original condition. None of them have escaped alteration in the course of the great post-Cambrian movements, and, speaking generally, the alteration is greater in this than in the other Torridonian sub-divisions. In the district between Loch na Dal and Kyle Rhea the epidotic grits lie to the east of most of the other rocks which can with confidence be claimed as Torridonian, and they, therefore, approach nearer to the region in which the thrusts and accompanying movements had their source. The areas in the southern part of Sleat lie in a network of thrusts, and have been considerably mylonised and crushed. Nevertheless, excepting in certain bands, the alteration has not gone far enough to produce a distinctly granulitic matrix, or to obscure the outlines of the larger constituents of the rock, which is crowded with determinable pebbles and clastic grains.

These rocks are least altered near Ardnameacan. In the coast-sections from half a mile to a mile north-east from this point the included pebbles have not been elongated nor is cleavage prevalent. North-eastwards indications of greater change appear: glistening foliation-planes often cross the bedding, the pebbles have been drawn out in a parallel direction, often across the bedding, and thin quartz-veins with some red felspar are occasionally seen.

The sub-division consists for the most part of grits and conglomerates, in which the fresh matrix shows prevailing tints of green or lemon yellow. The green tints are chiefly due to flakes of chlorite, the yellow to small grains of epidote or pieces of felspar which have been partially converted into epidote. The bands in which a yellow tint predominates are generally only from two to four inches thick. They are harder than the others, contain a greater proportion of quartz-grains, often of an opalescent character, and weather with a pale-buff or dirty-white colour. The greener parts, besides the chlorite, contain many grains and streaks of epidote, of red felspar, and of quartz, the latter often stained with hæmatite on their surfaces and along cracks. These colours form vivid contrasts in the shore-pebbles freshly washed by the tide. Some bands contain so many pebbles of red felspar that the green and yellow tints are hardly noticed. In many of the sections false-bedding is conspicuous—for instance, on the coast a quarter of a mile north-east from Rudha Guail.

The larger grains vary considerably in size in adjoining bands, but on the average they are bigger than those in any other of the Skye Torridonian rocks. In the beds half a mile south-west of the outlet of Loch a' Ghlinne, and half a mile north-east of that of Loch Lamarscaig (three miles N.N.E. of Point of Sleat), some pebbles or boulders exceed a foot in length, and are of such stout form that they cannot have been much elongated by shearing. These coarse beds probably lie near the base of the series. In the coarsest beds between Kyle Rhea and Loch na Dal it is rare to find pebbles exceeding the size of a pigeon's egg: towards the top of the sub-division the grains become smaller, and the grits are mixed with sandy shales, some of which have a green tint and are so mixed with thin laminæ of fine grit that the rock presents a ribboned appearance. Most of the high beds are greener than the lower, and are sometimes interstratified with grey beds like those in the Loch na Dal sub-division. It is noteworthy that the green colour is usually changed into black or grey in the neighbourhood of igneous intrusions.

Interstratified with the Epidotic Grits occasional bands may be seen of sandy purple, or variegated purple and green shale, which are unlike any other shales in the Diabaig group of Skye. Examples of them can be examined about 70 yards north-east from the foot of Allt Thuill.

In the areas half a mile south-west of the outlet of Loch a' Ghlinne, and half a mile north-east of that of Loch Lamarscaig, numerous large pebbles of opaque white quartz—apparently vein-quartz—may be observed, sometimes seven or eight inches long, and with their outsides stained with hæmatite. Other pebbles consist of opalescent quartz, which, though it never by itself forms pebbles as large as some of those of the other variety of quartz, not uncommonly occurs with felspar, either red or white, in pebbles which are of considerable size, and which have the aspect of many Lewisian gneisses. Most of the larger pebbles, too, which occur in a coarse band a little south of Port Aslaig, closely resemble some of these gneisses. That coarse band contains also pebbles of pink quartz-felsite, purple felstone, and quartzite. Such pebbles are generally common in the Applecross division, but rare in the Diabaig beds.

About 300 yards south-west of the foot of Allt Caillte some of the epidote grains are as large as hazel-nuts. In a slice (5413) prepared from a grit that occurs a quarter of a mile north-east of Dun Ruaige, many epidote grains are included within felspar pebbles. In the Loch a' Ghlinne and Loch Lamarscaig areas above referred to, some of the pebbles are composed of opaque white quartz and epidote, or of these substances and red felspar. Some of the pebbles, four or five inches long, show the epidote disposed in subparallel streaks.

It seems probable that the majority of these epidote or epidosite grains and pebbles consisted of their present substance at the time the beds containing them were formed. If they had been formed from felspar after the deposition of the strata, it is not likely that some felspar pebbles would have been left quite unaffected, nor would there probably have been such an intermixture of grits rich in epidote with others in which this mineral is scarce. Small grains of epidote are abundantly mixed with grains of other heavy minerals—magnetite, sphene, zircon, &c. —in thin parallel streaks, which represent the bedding of the rock, in various almost unaltered beds in other Torridonian subdivisions in Skye, and it is clear that these are clastic grains.

As has already been remarked, in various parts of the North-West Highlands the pre-Torridon surfaces of the Lewisian gneiss are abundantly traversed by strings of epidote, and the felspar folia have been more or less converted into epidosite. There is thus no difficulty in explaining how clastic grains of epidote should form part of the detritus that was first derived from such surfaces by denuding agents.

In some slides made from the rocks half a mile S.S.W. of the Loch a' Ghlinne outlet, broken bits of green hornblende occur in considerable abundance. One of the slides contains a number of grains of black iron ore.

In the areas half a mile south-west of Loch a' Ghlinne outlet, and half a mile north-east of Loch Lamarscaig outlet, the pebbles of quartz and of rocks resembling massive Lewisian gneisses are not generally much flattened nor elongated in a parallel direction, though they are crossed with small crush-lines and sometimes bent. Intimately mixed with these stout pebbles, however, are others composed of highly-sheared material, which are flatter and longer, some being a foot long though only one or two inches thick, in a direction across their foliation. It seems probable to the writer that the flat pebbles referred to had nearly the same form as now at the time of their incorporation in the bed, and that the parent rocks from which they were derived were finely sheared in pre-Torridon times. If these parent rocks were finely sheared we should expect the pebbles from them to be of a flattish form, much as we find in pebbles made from shale. The long axes of these flattish pebbles lie in parallel planes, but they have no general direction, and in one pebble (Slice 7843) of mylonised substance the shear-planes continue distinctly up to the edge and there end, without entering the enclosing matrix, and the long axes of the quartz grains in the matrix are not parallel to the shear-planes in the pebble. We may, therefore, conclude that somewhere near the area of deposition of the conglomerate there was an exposure of pre-Torridon mylonite, probably of the same age as those near Loch Maree. The mylonised pebble represented in Slice 7843 is composed of alternating water-clear and opaque white granulitic layers with small augen of red felspar—plagioclase in part—and macroscopically it resembles two rocks which occur *in situ* in the neighbourhood, one a Lewisian gneiss and the other a granulitised band of the Moine series.

It is not certain that in Skye the base of the Epidotic Grits is anywhere seen. The conglomerate half a mile south-west of the Loch a' Ghlinne outlet is folded as well as crushed, and perhaps the original thickness need not exceed 80 or 100 feet. The Epidotic beds between Allt Thuill and Allt Caillte are perhaps 200 or 300 feet thick.

b. Loch na Dal Beds.—The chief outcrop of the Loch na Dal sub-division extends from Kyle Rhea to Loch na Dal. Near Meall Port Mealary and Rudha Guail the beds are folded to a considerable extent, and the outcrop is of irregular form. The greatest width (which is near Loch na Dal) is two-thirds of a mile. Outcrops, which are no doubt continuous under the Sound of Skye with this band, are exposed in good coast-sections on the east side of Kyle Rhea, and on the south-west side of Loch na Dal. The first-mentioned outcrop, which may be seen on the north side of Glenelg Bay, is not in most places more than from 20 to 40 yards wide. The outcrop on the south-western side of Loch na Dal is covered by rocks brought forward on the Moine thrust.

The sandy or gritty shales, which form a large proportion of the sub-division, are usually of a dark-grey colour, but weather with a brown crust. The purer shale laminæ are mixed in extremely thin alternations with sandy or gritty material. Very often ten or twelve such layers may be counted in the thickness of an inch, and it is rare to find more than an inch of pure shale. Some of the clastic grains in the gritty layers are as large as peas, and isolated grains of this size may lie in rows in the shale.

This close intermixture of fine and coarse material is a marked feature in the sub-division, though not confined to it, for a similar rapid alternation, though perhaps not in quite so striking a form, is to be found in the Kinloch sub-division. The surfaces of the laminæ often display abundant flakes of white sedimentary mica and ripple marks.

The sandy shales are intermingled with thin bands of sandstone or grit, of a greenish-grey colour, which split along the bedding into rather thin slabs, and generally contain grains of quartz and felspar which are large enough to be discerned by the unaided eye. The quartz-grains are often slightly opalescent, or of a pale blue colour. The felspar grains are either red or white, and not granulitised. In Specimen 7704, a slightly altered gritty shale from the shore a little more than a third of a mile north-east from Ardnameacan, the dark bands are too fine-grained to be capable of satisfactory determination even under the microscope, but are probably in the main composed of granules of quartz and flakes of micaceous minerals.

The sub-division includes some massive grits which, when fresh, have a buff or greenish-grey hue, but which weather with a buff crust, suggestive of the presence of some finely-diffused ferriferous carbonate. These grits are most abundant near the top of the sub-division, and they so closely resemble most of the Beinn na Seamraig grits that in places no satisfactory boundary can be drawn between them.

Thin calcareous streaks and lenticles, rarely more than six inches thick, and weathering with a brown colour, are common in the gritty shales and grits. Most of them are full of clastic grains of quartz and felspar, which project on the weathered faces.

At Port Aslaig, and between that little bay and Allt Thuill, the shore exposes bands of purer and blacker shale than commonly occur, one of them being somewhat calcareous. In the little burn north-east from Allt an Doire-daraich this bed of shale is perhaps 18 or 19 feet thick, but only a small proportion of it has a calcareous composition.

The thickness of the Loch na Dal beds seems to increase southwestwards from Kyle Rhea to Loch na Dal. Although the outcrop on the coast north of Dun Ruaige is not sharply defined either from the Beinn na Seamraig grits above or from the Epidotic Grits below, the thickness of the sub-division there is estimated at about 600 feet. On the north-east side of Loch na Dal the width of outcrop is partly increased by folding, but, after making allowance for this reduplication, there still seems to be more than twice the depth of strata visible near Kyle Rhea, which is only about six miles away. There may possibly, however, be some deceptive structure in the Loch na Dal section which has escaped notice.

c. Beinn na Seamraig Grits.—This sub-division is named after a hill two miles north-east of Loch na Dal, whence it can be traced in a north-easterly direction over Ben Bheag, Ben Aslak, and Beinn Bhuidhe, to the Kyle Rhea, of which it forms the western, and a narrow strip on the eastern, shore. Towards the south-west it passes by the head of Loch na Dal and over A' Mhaoile. A little south-west of this hill the lower beds begin to be covered by rocks brought forward on the Moine thrust, and about half a mile south-east of Cnoc Bealach na Coise the whole outcrop is hidden.

The base of these grits forms a somewhat even line, excepting about a mile south-west of Port Aslaig, where it is folded along axes striking north-east. Their top is a little uncertain between Beinn Bheag and Allt Eas a' Mhuic, north of the village of Kylerhea. Near the head of Glen Arroch it strikes nearly east and west for a mile and a half. The width of the outcrop varies considerably. On Ben Aslak, where greater than anywhere else, it is about two miles and a half.

To the south-west of Cnoc Bealach na Coise (about two miles W.S.W. of Isle Ornsay) it is not certain that any of the Beinn na Seamraig grits emerge from beneath the Moine thrust until the head of Allt a' Mhuilinn, west of Ostaig. Some massive grits, however, near Loch Mhic Charmichael may possibly belong to this sub-division.

The only coast-sections in which this sub-division is exposed are those in Kyle Rhea, and in these the rocks are much more altered than further south-west.

Most of the grits near the top of Beinn na Seamraig are massive, fine-grained, and of a greenish-grey colour, but they weather with a pale-buff crust. The clastic grains do not often exceed the size of peas. Many of the quartz-grains are opalescent and of a pale-blue colour. On the coast 300 yards south of the foot of Allt a' Choire Bhuidhe (one mile north of Kylerhea), we noticed some pebbles containing both quartz and felspar, and others that resembled jasper. Some of the finer grits—for instance, those on the north-east side of the burn about 1000 yards east of Beinn Bheag—show thin dark-grey streaks containing clastic grains of some black iron ore. Occasionally the grits are so fine-grained and compact as to resemble quartzite, as may be seen on the south side of Beinn Bhuidhe and on the coast 50 yards south of the foot of Allt a' Choire Bhuidhe: the colour of these bands is a greenish-grey, not white.

Specimen 7679, of a considerably altered grit from the shore a little more than three-quarters of a mile W.N.W. of the south end of Bernera, has been analysed by Mr Teall with the following result:—

Si_2O	73·56
Al_2O_3	13·62
Fe_2O_3	2·3
CaO	1·04
MgO	Trace.
K_2O	4·24
Na_2O	3·98
Loss on Ignition	1·08
	99·82

Intercalated shale-bands are seen near the top of Ben Aslak, a third of a mile north-east of the top of Beinn na Seamraig, and at many other places near the top and bottom of the sub-division. They are always closely mixed with laminæ of sandy or gritty material, and generally weather with a somewhat deeper brown tint than the grits with which they are intermixed. Near the top of the sub-division the proportion of shale usually increases upward in the series, and in most places, particularly near the head of Glen Arroch and Allt Eas a' Mhuic, the top itself is consequently ill-defined.

At the head of Loch Eishort the dip is constantly north-west, though the amount varies. There is no reason to suspect here a repetition by folding. The width of the Beinn na Seamraig outcrop being not less than a mile, the estimated thickness of the sub-division is 2600 feet. In areas further to the north-east it is also necessary to admit a great thickness of these strata.

d. Kinloch Beds.—The strata between the Beinn na Seamraig grits and the Applecross group are well seen near Kinloch, at the head of Loch na Dal; hence the name of that place has been taken to designate them. The proportion of shale in this sub-division is probably less than that of grit, but considerably greater than that in the sub-divisions above and below. The Kinloch Beds cover more ground in Skye than any other member of the Diabaig group, and about the same as the Applecross rocks. Their chief outcrop extends from Loch Alsh to the northern tributaries of Abhuinn Glinne Mheadhonach—a distance of 16 or 17 miles in a south-westerly direction. It then bends to the north, but at Tokavaig twists back into its previous course, and runs out to sea between Ob Gauscavaig and Tarskavaig Bay. All the islands in this bay, except Sgeir Fhada and Sgeir Biodaig, are composed of beds belonging to this sub-division, likewise a narrow interrupted strip extending along the coast for about a mile south of the bay. Between the Loch an Eilean north-west fault and Tokavaig, the boundary between this subdivision and the higher rocks is a thrust, along which the lower rocks have been pushed over the higher, and near Loch Meodal and Loch nan Uamh the base of the sub-division is covered by gneiss brought forward by the Moine thrust. Among several small detached areas, one is found in the upper part of Allt a' Mhuilinn and four in the complicated region near Ord.

Coast-sections in which the Kinloch Beds may be examined occur in Loch Alsh, at either side of Loch Eishort near the head. and between Ob Gauscavaig and Tarskavaig Bay. The sections near Kinloch lie in deep burns, which keep along the strike of the more shaly beds for considerable distances. Grits in the division make the rocky slopes of Carn an t' Seachrain, Beinn na Caillich, and Sgurr na Coinnich (west of Kyle Rhea). Like the other Diabaig grits, these rocks are harder than the Applecross grits, and have resisted denudation better.

The shales of the division bear a close resemblance to the Loch na Dal shales. The sandy laminæ intermixed with the shales are not, however, so coarse grained, as a rule, as those in the Loch na Dal division, and the calcareous lenticles are less numerous. The sedimentary layers of magnetite and other heavy minerals are, on the other hand, thicker than in the Loch na Dal division, and there are more bands of massive fine-grained grit.

In Glen Arroch the width of outcrop is about a mile and 300 yards, and the calculated thickness is 3500 feet. Between the head of Loch Eishort and Loch na Dal the thickness is probably still greater.

Different horizons in the division vary considerably in character, and in some places there are very thick grits. In the neighbourhood of Kinloch there are thick grits near the top of the division, and the boundary between the Kinloch and the Applecross rocks represents a boundary between different types of grit rather than between grit and shale.

On the south side of Tokavaig, after passing through the passage beds between the Applecross and the Kinloch beds, we reach a set of shales of considerable thickness. Below these, but in their present position over them, as all the beds in this locality are inverted, there is a series of grits, fine-grained, spotted, and red or reddish-brown in colour; bands of shale occur between the grits, but the proportion of grit throughout a horizon 800 or 900 feet thick is evidently large.

In specimen 5068, from a grit a mile W.S.W. of Sgurr na Coinnich, grains of oligoclase are more abundant than in the Applecross beds, but they are accompanied with grains of microcline and microperthite. In specimen 5069, from a fine grey grit near the head of Allt na Pairc-fraoich (two and a half miles south of Kyle Akin), the same three felspars occur.

The beds near the top and bottom of the sub-division usually contain the greatest proportion of shale. The best sections of the shaly beds near the top are to be seen on Rudha Ard Treshnish (Kyle Akin), at the head of Loch Eishort, near Mullach an Achaidh Mhoir, and near the centre of Ob Gauscavaig. At the first two places impure calcareous lenticles, resembling those in the Loch na Dal division, are common. The shaly beds near the base appear near Rudha na Caillich, three-quarters of a mile south of Sgurr na Coinnich, and in burns near Kinloch. It is doubtful whether calcareous lenticles occur in these beds. The grits interbedded with the shales near the base contain dark layers of heavy clastic grains, which sometimes include so many of magnetite as to disturb the compass at a distance of a few feet. One layer of this kind, detected in a grit about 100 yards slightly north of east from Sgurr na Coinnich, is from an inch to an inch and a half thick, but cannot be traced more than a few yards. A specimen (5071) from this layer is divisible into two halves, one of which attracts the north pole and repels the south pole of the compass, while the other does the opposite: the dividing plane is oblique to the bedding. Mr. Allan Dick, who has been so good as to examine the rock for the Survey, reports that the rock contains 27.5 per cent. of metallic iron, equivalent to 37.97 per cent. of magnetite. The microscopic slide shows magnetite in crystals and crystal groups, zircon, a brown substance apparently in part micaceous, and a little quartz and felspar. This layer dips south-east at about 34°. A second layer, noticed in a grit on An Sgulan, is in one place six inches thick, but the lower part is not so rich in magnetite as the rest. This layer occurs about 200 or 300 feet above the base of the sub-division, and is probably on about the same horizon as that on Sgurr na Coinnich. Thinner layers, rich in magnetite and other heavy minerals, are not uncommon at higher horizons.

In spite of the false-bedding, the sub-division generally contains such distinct alternations of material along bedding planes that there is seldom any doubt about the true dip, and in this respect it offers a striking contrast to the Applecross group. Ripple-marks are common on the surfaces of the finely-laminated sandstones and sandy shales. They have been unusually well exposed on the coast south-west of Ob Gauscavaig. Clastic scales of white mica are abundant on many of the same surfaces. Rain-pitted shales may be seen in the burn north-east of Kinloch.

(2) *Applecross Group.*—The arkoses or grits of this sub-division form a band which, stretching south-westward across the island from Kyle Akin to Loch an Eilean, in Loch Eishort, is covered unconformably on the north-western side by the Mesozoic rocks, and on its south-eastern margin is succeeded by the Kinloch Beds, which lie conformably below. In a south-westerly direction from the road between Broadford and Isle Ornsay the breadth of the band decreases, until on the north-eastern side of Loch an Eilean it hardly amounts to three-quarters of a mile. A large fault, which, with downthrow to the north-east, crosses Loch Eishort, through Loch an Eilean, and runs up the burn between Ben Vokie and Monadh Morsaig, has had the effect of lifting up on its south-western side a thrust-plane, together with a group of rocks that lie below this plane, while on its north-eastern side these underlying rocks are hidden under the Torridonian strata which overlie the plane. This set of lower rocks, much disturbed by thrusts and folds, includes several isolated exposures of the Applecross group. The thrust-plane has been folded into an anticline along an axis striking north-eastwards. On the west side of the western limb of this folded thrust another detached band of Applecross beds forms Sron Daraich and Druim Dubh, on the south side of Loch Eishort, and runs out to sea at Ob Gauscavaig. It lies above the thrust-plane, and may have been continuous with the Kyle Akin and Loch an Eilean band before the formation of the fault which crosses the loch. The Torridonian rocks near Ben Suardal belong exclusively to the Applecross group. They have been thrust over Cambrian limestone, and the thrust-plane below them has been folded into an anticline with an axial plane striking N.N.E.

The best sections of the Applecross group in Skye are to be seen on the coast between Ob Lusa and Kyle Akin and on the north-east side of Loch an Eilean. The most common rock is a chocolate or purple-red arkose or grit, in which the larger grains, chiefly consisting of red felspar and quartz, do not exceed the size of a small mustard seed. Occasionally—as, for instance, on the coast a quarter of a mile north-west of Sgeir Gormul—coarser bands may be noticed, in which the grains are as large as peas, but for the most part the rocks, here as in the Loch Carron district, are finer in grain than those of the same group in Applecross and in the country further to the north. The quartz-grains are often somewhat opalescent. Grains and pebbles of composite rocks are common. Though generally smaller than in more northerly districts, they yet frequently exceed in size any of the quartz and felspar grains which occur in company with them, some of them being an inch in length. Among the materials of these composite pebbles, pegmatite, red felstone, red porphyrite, arkose, vein-quartz, jasper, and pink and purple quartzite have been observed.

False-bedding is so prevalent and marked that the true dip can often only with difficulty be determined. Here, as in the other districts already described, the minor laminæ within the thicker beds are sometimes arranged in irregular curves, while the surfaces of these beds retain a uniform slope. (See Fig. 13.) Good examples of this structure may be seen on the coast near Kyle House; likewise on the east side of Loch Lonachan (three miles south of Broadford), near the upper end, where the curved lamination is shown by thin streaks with many black clastic grains. Similar streaks are common throughout the group. Characteristic instances of these can be observed in the south-eastern part of Eilean Heast (Loch Eishort). In a specimen from the northern coast, a quarter of a mile south-west of Ob Allt an Daraich (two and a half miles W.S.W. of Kyle Akin), some layers are composed mainly of quartz and felspar with epidote and a little chlorite, while the dark layers contain a great number of grains of ilmenite and epidote. Other forms of iron-ore have also been observed to be disseminated in the Applecross group of Skye. Thin streaks and lenticles, often about an inch thick, of a deep purple tint, can frequently be seen to keep parallel with the bedding, as in Eilean Heast, on Loch Eishort, and on the northern coast 350 yards E.S.E. of Bogha an t-Sasunnaich (two miles west of Kyle Akin). Nearly half a mile E.N.E. of the market stance, Skulamus (two miles E.S.E. of Broadford), thin laminæ of hæmatite, hardly $\frac{1}{20}$-inch thick, have been noticed, also running parallel to the bedding. Scars formed of rocks of this group often weather with more rounded outlines than do those formed of the Diabaig grits. Some exposures show spots, about the size of a pea, and of a brighter red tint than the matrix, which are probably of the same nature as those already referred to in the Diabaig grits. Thin calcareous lenticles have been observed in the grits on the coast 360 yards S.S.E. of Bogha an t-Sasunnaich and a few neighbouring localities.

Besides the predominant sandstones and grits or arkoses, subordinate thin bands of shale may be observed on various horizons in the group. These are red, purple, or green in colour, but towards the base of the group are of a dark-grey tint, and they then resemble those of the underlying Kinloch Beds.

The breadth of the Applecross group between Skulamus and the outcrop of the Kinloch sub-division near Allt Cul Airidh Lagain is about two and a quarter miles, and the calculated thickness of strata amounts to 5000 feet; but as the top of the group has not been detected anywhere in Skye, it is impossible to say how much of the original depth of the group here is no longer to be seen.

The only part of the group which seems appreciably altered by dynamo-metamorphism lies near Kyle Akin and between Kyle Akin and Ob Allt an Daraich. The alteration is there shown by the occasional presence of cleavage, and of thin veins of quartz with specks of felspar. Traced diagonally across the strike from Kyle Akin towards Ob Allt an Daraich, the strata show a diminution both of the cleavage and of the veins, as if the metamorphic change were dying out in a north-westerly direction. Towards the south-west, along the strike of the strata from Kyle Akin, the cleavage and the quartz-veins in like manner become less prominent; they were not noticed either in Allt Mor or at the head of Loch Eishort, nor anywhere else in the Applecross group of Skye. Many of the veins of quartz and felspar contain a little chlorite also. While most of them are less than an inch wide, some reach a width of six inches. They are well seen a little west of Caisteal Maol (Kyleakin), and near Kyle House, where they generally incline to the north-west, and, though of short extent individually, are closely crowded together in certain bands of rock.

Near the base of the Mesozoic rocks, the Applecross arkoses appear to have been deeply weathered and jointed prior to the deposition of these overlying sediments, and they have also been partially stained with a deep Indian red colour. In the area between Glac an Skulamus (two miles south-east of Broadford) and the head of Allt Garbh, and at the sides of Allt Lochan Dubh na Bric, the chief joints and splitting planes are of a deep Indian red tint, while the heart of the rock is paler and presumably free from staining. In some places, for example near the bridge over Abhuinn Ashik (three miles east of Broadford), and, again, nearly a third of a mile north-east of the outlet of Loch Buidhe (two miles and a half south of Broadford), the arkoses are crossed by so many irregular calcareous streaks and veins of limestone, the substance of which has no doubt been derived by percolation downwards from the overlying Mesozoic beds, that the plane of junction between the arkoses and these overlying beds is not readily ascertained.

At the sides of many of the Tertiary dykes, the Applecross beds assume a somewhat conchoidal fracture and a dirty buff or straw colour like that already noticed as conspicuous in the Crowlin Isles and elsewhere. Much the same colour is also found near certain lines of crush and the Ben Suardal thrust-plane. In certain places near Broadford, as, for instance, in Allt a' Mhuilinn and on the hillside half a mile S.S.W. of the Established Church, they have assumed the above colour in their general mass and have also been veined and spotted with green epidote, presumably in consequence of the influence of some underlying mass of Tertiary igneous rock which is not exposed.

PLATE XXXIII.

Cambrian Quartzite resting unconformably on eroded platform of Lewisian Gneiss. Beinn Arkle, Sutherlandshire.

PART III.—CAMBRIAN.

SECTION I.

CHAPTER XXII.

GENERAL ACCOUNT AND DISTRIBUTION OF THE SYSTEM IN THE NORTH-WEST HIGHLANDS*, WITH A DISCUSSION OF THE CONDITIONS OF DEPOSIT INDICATED BY THE STRATA.†

The detailed examination of the region between Durness and Skye has furnished ample evidence of the unconformability between the Torridon Sandstone and the overlying Cambrian formations, originally established by Professor Nicol and independently by Sir Henry James. From the relations of the strata it is obvious that the conditions of sedimentation which prevailed in Torridonian time were interrupted throughout the North-West Highlands, and that thereafter important movements of the terrestrial crust here took place, followed by extensive denudation of the pre-Cambrian rocks. As already indicated, the denuded surface thus produced differs widely from the deeply-eroded surface of Lewisian gneiss beneath the Torridon Sandstone. Instead of an undulating plateau carved into hills and valleys, the platform on which the Cambrian strata were deposited, composed in certain areas of Lewisian gneiss, in others of Torridon Sandstone, and in some cases partly of both, was reduced to a great plane probably of marine denudation. (See Plate XXXIII.)

The persistence of this plane is, indeed, one of the prominent structural features of the region. That it represents the sea-floor on which the Cambrian sediments were laid down may be confidently inferred. Where the Cambrian basal beds rest on the gneiss the latter has undergone a peculiar phase of decomposition; in particular the felspar has been changed into agalmatolite, as noted by Professor Heddle. Where they lie on Torridonian strata the latter are bleached and the felspars are kaolinised, thus contrasting in a marked degree with the normal development of the red sandstone. Lastly, a fine conglomerate or pebbly grit, from a few inches to two feet in thickness, occurs at their base.

In certain sections in Ross-shire, where the red sandstones and overlying Cambrian strata dip in the same general direction, and

* By J. Horne.

† By B. N. Peach.

where there is no great difference in the angle of inclination of the respective beds, the discordance is not readily detected. But such instances are exceptional. As a rule, the red sandstones are either horizontal or inclined to the E.S.E. at lower angles than the quartzites, and hence they are transgressed, bed after bed, by the basal quartzites, which eventually come to lie directly on the Lewisian gneiss. This double unconformability is admirably displayed on the slopes of Ben Garbh, along the southern shore of Loch Assynt, and on Canisp. (See Fig. 36, which gives a section from Canisp by Breabag to River Oykel).

In the rock-masses displaced by the post-Cambrian movements, confirmatory evidence is obtained of the unconformable relation between the Torridonian and Cambrian strata. The detailed mapping of the region has proved that the original eastern limit of the red sandstones lay far to the east of the areas not affected by these movements. In Assynt, Sutherlandshire, the disrupted materials contain representatives of the Applecross and Diabaig groups of the Torridon Sandstone with the conglomerate at their base. These are overlain by the Cambrian quartzites, which pass transgressively across the red sandstones to the Lewisian gneiss, thus furnishing excellent examples of the double unconformability. Similar relations, though on a less conspicuous scale, have been recorded in Ross-shire. Again, in some of the thrust masses outliers of red sandstone occur, indicating marked erosion in pre-Torridonian time.

It is obvious, therefore, that during the interval which elapsed between the deposition of the Torridon Sandstones and Cambrian quartzites, the former were thrown into a series of gentle folds; a vast thickness of them was then removed, so as to expose the Lewisian rocks over wide areas, and the surface of the region was reduced to a fairly uniform plane, as shown in the accompanying diagram. (Fig. 16.)

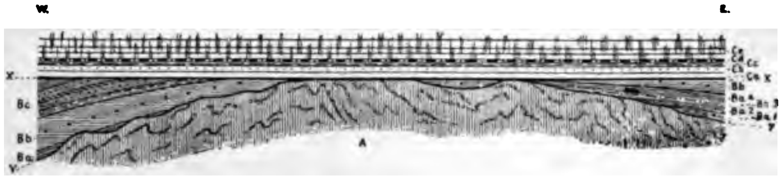


Fig. 16.—Diagram showing the Formation of Outliers of Torridon Sandstone by folding and denudation in Post-Torridonian and Pre-Cambrian time.

A. Lewisian Gneiss.
Ba—Bc. Torridonian.
Ca—Ce. Cambrian.
Y. Pre-Torridonian surface of erosion.
X. Pre-Cambrian plane of marine denudation.

A remarkable feature of the Cambrian series of strata in the North-West Highlands is the uniformity of their order of succession along the narrow belt extending for 100 miles from Loch Eireboll to Skye. All the important zones, and even the minor sub-divisions, have been traced with little variation in their respective thicknesses throughout that region.

The Cambrian sediments form three well-marked divisions:— A, a lower arenaceous series composed wholly of quartzites, the upper portion being crowded with worm burrows; B, a middle series, partly calcareous and partly arenaceous, comprising the fucoid beds and *Salterella* grit; C, an upper calcareous division, including dolomites and limestones. The discovery of the *Olenellus* fauna in members of the middle division in 1891 furnished a definite horizon from which to work out the stratigraphical succession above and below. Fragments of *Olenellus* have been found in the fucoid beds at various localities along the line between Loch Eireboll and Sleat in Skye, thus proving beyond doubt the continuity of the zone.

In certain areas in the counties of Sutherland and Ross the pipe-rock zone of the quartzite has been divided into five horizons, in accordance with the nature of the worm burrows and the lithological character of the strata. At the top of the third sub-zone (see Part III., Section IV.—vertical section showing horizons of intrusive rocks in Cambrian strata), a massive band of quartzite has yielded *Salterella* similar to that found in the *Salterella* grit. This discovery links the quartzites with the *Olenellus* zone, and hence the base line of the Lower Cambrian division has been drawn at the bottom of the arenaceous series.

The succession of dolomites and limestones, with an aggregate thickness of about 1500 feet, has been arranged in seven groups. The lowest of these (Ghrudaidh group) has been further subdivided into several zones, of which the most important are the two bands of dolomite charged with *Salterella*. The upper limit of the Lower Cambrian formation has, therefore, been placed in this sub-division above the horizon of these fossiliferous bands.

The total thickness of Cambrian strata in the North-West Highlands is about 2100 feet. The various sub-divisions into which the whole series has been grouped are given in descending order in the subjoined tabular statement:—

VERTICAL SECTION OF CAMBRIAN STRATA.

Middle and Upper.	C. Calcareous Series.	VII. Durine Group.	Fine-grained light grey dolomites and limestones, with an occasional fossiliferous band.
		VI. Croisaphuill Group.	*c*. Fine-grained, cleaved, lilac-coloured limestones, full of flattened worm-casts; fossils distorted by cleavage.
			b. Alternations of black, dark-grey dolomite and white limestone, with an occasional fossiliferous band, like zone (*a*) of this group.
			a. Massive dark-grey dolomite and limestone, chiefly composed of worm-casts, which project above the matrix on the weathered surfaces. Near the base are several lines of small chert nodules. This is one of the most highly fossiliferous zones in the Durness basin.

Middle and Upper—*continued.*	C. Calcareous Series—*continued.*	**V. Balnakiel Group.**	**Alternations of dark and light-grey dolomite, with some bands of limestone, highly fossiliferous; occasional impure unfossiliferous layers with dark cherty nodules. Most of the beds are distinctly cleaved and contain few worm-casts.**
		IV. Sangomore Group.	**Fine granular dolomites, alternating near the top with thin bands of cream-coloured or pink limestone. Near the base are two or more bands of white chert, one of which is about five feet thick.**
		III. Sailmhor Group.	**Massive crystalline granular dolomites, occasionally fossiliferous, charged with dark worm-castings set in a grey matrix; large spheroidal masses of chert near the base. This rock is locally known as "the Leopard Stone."**
		II. Eilean Dubh Group.	**Fine-grained, white, flaggy, argillaceous dolomites and limestones, with chert bands between Assynt and Skye. No fossils have been found in this division.**
		I. Ghrudaidh Group.	**Dark leaden-coloured dolomites, occasionally mottled, alternating near the top with white limestone. About thirty feet from the base there is a thin band of dolomite charged with *Salterella* (Serpulites), and a similar band occurs at the base.**
Lower.	B. Middle Series, partly calcareous and partly arenaceous.	Upper Zone.	**At the base lies a massive band of quartzite** and grit, passing upwards into carious dolomitic grit, crowded in patches with *Salterella*, more especially in the decomposed portions ("Serpulite Grit").
		Lower Zone.	Dolomitic shales, mudstones, and dolomitic bands, weathering with a rusty colour, traversed by numerous worm-casts, usually flattened and resembling fucoidal impressions, yielding *Olenellus*, *Salterella*, *Hyolithes*, &c. Lenticular beds of flaggy dolomitic grit and quartzite are locally developed ("Fucoid-beds").
	A. Arenaceous (Quartzite) Series.	Upper Zone.	Upper fine-grained quartzites, perforated by vertical worm-casts and burrows (*Scolithus*), which become more numerous towards the top of the zone ("Pipe-rock"). This zone has been sub-divided into five sub-zones, each distinguished by its peculiar type of "pipes."
		Lower Zone.	Lower false-bedded flaggy grits and quartzites, composed of grains of quartz and felspar. At the base there is a thin brecciated conglomerate, varying from a few inches to about two feet in thickness, containing pebbles chiefly of quartz and felspar, the largest measuring about two inches in diameter.

In the continuous belt of Cambrian strata that stretches throughout the counties of Sutherland and Ross from Loch Eireboll to Loch Kishorn, a well-defined line separates the undisturbed strata to the west from those which have been affected by the post-Cambrian movements to the east. Owing to these displacements, the width of this belt varies considerably. On referring to the geological map accompanying this memoir, it will be seen that, for many miles to the north and south of Loch Broom, it is less than a mile across, while in the mountainous region of Assynt, where Cambrian, Torridonian, and Lewisian rocks have been repeated by successive thrusts, it is about eight miles broad.

The prominent members throughout this belt are the quartzites, which, in the area unaffected by the great lines of thrust, give rise to conspicuous features in the landscape, sometimes appearing as outliers capping lofty mountains of Torridon Sandstone or Lewisian gneiss, and again forming gently-inclined slopes dipping towards the E.S.E. They have likewise a remarkable development in the displaced masses in Assynt and throughout the tract of deer forest between Kinlochewe and Strathcarron.

The so-called "Fucoid-beds," 40 to 50 feet thick, are frequently concealed by a covering of vegetation, and hence good sections, particularly of the higher bands that yield the *Olenellus* fauna, are rare. Nevertheless, owing to the composition and structure of the dolomitic shales and their mode of weathering, their outcrops are readily traced alike in the undisturbed and disrupted areas. The exposures that have furnished the best preserved specimens of *Olenellus* and its associates occur in the unthrust area in the Dundonnell and Kinlochewe deer forests, but the same zones are frequently to be met with in the displaced masses on the mainland, though organic remains in such cases are not readily found.

In like manner the Serpulite (*Salterella*) grit, about 30 feet thick, forms a well-marked horizon from Loch Eireboll to Loch Kishorn, where it usually gives rise to a small escarpment between the underlying fucoid beds and overlying basal limestone.

The distribution of the dolomite and limestone in the counties of Sutherland and Ross is of special interest, as it illustrates the complicated geological structure of that region. In the Durness basin on the north coast of Sutherland, where the Cambrian strata have been disconnected from those at Eireboll by faulting and denudation, the dolomite and limestone form the predominant members. Indeed, nowhere else in the North-West Highlands do we find the complete sequence of the calcareous series given in the foregoing vertical section. In that isolated area there are excellent exposures of the two richly fossiliferous sub-divisions. (Group V., Balnakeil, and Group VI., Croisaphuill.) But along the line of complicated structure between Loch Eireboll and Loch Kishorn the dolomite and limestone usually appear as lenticular strips or patches, save at Eireboll

House, at Inchnadamff, and at Kishorn, where they occupy considerable areas. The outcrops are interrupted by reversed faults or powerful thrusts, which bring forward lower beds or repeat the basal zones of the calcareous series. The highest beds along the belt between Eireboll and Kishorn belong to the Sailmhor dolomites (Group III., vertical section, p, 366), which appears on the limestone plateau of Inchnadamff. No member of the highly fossiliferous zones of Durness has yet been detected along the line of complication in the counties of Sutherland and Ross. The *Orthoceras* found by Mr. Charles Peach in Assynt must have come from one or other of the bands of dolomite charged with *Salterella* at the base of the Ghrudaidh group.

That the Cambrian rocks originally extended further west on the mainland is clearly proved by the occurrence of a patch of the basal quartzites at Achiltibuie, beyond the Coigach Mountains, Ross-shire—about nine miles to the west of the existing main belt—where they have been let down by normal faults in the midst of the Torridon Sandstone. In the sequel (Part IV.) it will be shown that before they were disrupted and piled up by the post-Cambrian movements, the Cambrian formations must have spread over the territory for miles to the east of their present limits.

In Skye the members of this system have only a limited distribution, being restricted to certain areas near the Ord in Sleat and to the tract between Broadford and Loch Slapin. All these exposures have probably been affected by the great post-Cambrian displacements. There is perhaps one exception, to which attention will be directed in the sequel (Part IV., Chap. XXXIX.) Among the various thrust masses in this island, evidence has been obtained of the unconformability between the Torridon Sandstone and Cambrian strata. Near the Ord, all the main Cambrian zones, ranging from the basal quartzites to the Sangomore dolomites and limestones (Group IV., vertical section, p. 366) have been met with, while to the west of Broadford, at Ben Suardal, there are representatives of the Balnakiel and Croisaphuill Groups, as first pointed out by Sir A. Geikie.* Indeed, it is worthy of note that all the sub-zones of the pipe-rock zone of the quartzite have been identified in Sleat, that fragments of *Olenelloides* have been found in the fucoid beds in the Tokavaig burn near the Ord, and that a suite of fossils characteristic of the Balnakeil and Croisaphuill zones has been obtained from the dolomites and limestones at Suardal.

Conditions of Deposit indicated by the Cambrian Strata of the North-West Highlands.

From the distinctive lithological characters of the various Cambrian sediments, and from the nature of the enclosed organic remains, some probable conclusions may be drawn as to the conditions under which the Cambrian series of the North-West

* *Quart. Journ. Geol. Soc.*, vol. xliv., p. 62.

Highlands was accumulated. The extensive denudation which produced the wide submarine plane on which this series of strata was laid down must have required a prolonged period of time for its accomplishment. During this protracted interval the ancient land, composed of Lewisian and Torridonian rocks, was planed down to the sea-level or perhaps just beneath it. Upon a portion of this plane which was being subjected to earth-stresses, applied in a north-west and south-east direction, and thus at right angles to those which plicated the Lewisian rocks, the Cambrian coast line was determined with a north-east and south-west trend. South-east from that shore the Cambrian strata were deposited in a continuously deepening ocean.

The conglomerate, never exceeding a few feet in thickness, which lies at the base of the Cambrian series, is made up chiefly of quartz pebbles, which represent the residue of the hardest materials of the older rocks beneath. It is followed by the lower quartzite, which over the whole area presents a remarkably uniform thickness of about 200 feet, pointing to the deposit of sandy and gravelly sediment parallel to and not far from the shore line. From its frequently pebbly character and its persistent more or less false-bedded structure, this quartzite appears to have been accumulated rapidly in comparatively shallow water subject to considerable current-action. In the northern part of the region it contains few or no intercalations of shale, but towards the extreme south and south-west, beds of micaceous shale, sometimes 10 feet thick, make their appearance towards the base of the group, showing that the "mud-line" was occasionally reached in that direction. Few or no organisms have left their traces in this quartzite zone.

During the accumulation of the upper quartzite quieter conditions of deposit seem to have prevailed in slightly deeper water further from the shore. The sea-floor was probably subsiding more rapidly than could be compensated by the deposition of sediment, though a reversion to former conditions may have prevailed for a short time while the members of the sub-zone of the "trumpet pipes" was being laid down, perhaps during a pause in the downward movement. After this episode, however, the depression appears to have been renewed at a more rapid rate than ever, for the topmost bed of the "pipe-rock" is in places studded with glauconitic grains, which are known to accumulate in comparatively clear water. Throughout the whole period of time represented by the upper quartzite the fine white siliceous sand probably settled slowly on the sea-bottom amidst much organic matter, with which it became so commingled as to be swallowed by millions of such worm-like creatures as have left their burrows and casts in vast abundance in the rock. To these cylinders of indurated sand the name of "pipes," given by Nicol, from their fancied resemblance to the stems of tobacco-pipes, has generally been adopted by succeeding geologists.

Following upon the "pipe-rock," the so-called "fucoid-beds" indicate a still further subsidence and greater distance from shore. The "mud line" had now been reached, although the sandy dolomitic beds in the lower portion of the zone may represent occasional reversions to the conditions under which the upper quartzite was formed. Nevertheless, the succession of sediments shows that before the uppermost portions of this zone were laid down the "mud-line" was not only reached, but even at times was overstepped, so that pure organic deposits were allowed to accumulate. On this clear and tranquil sea-bottom the dead organisms were subjected to the solution of their calcareous portions and the partial replacement of their lime by magnesian salts from the sea water, whereby dolomitisation was produced. The same strata also contain a considerable amount of phosphate of lime, evidently derived from the decomposed tests of such organisms as trilobites and hingeless brachiopods, which appear in considerable numbers in some of the bands. As a further indication of the depth and clearness of the water, it may be added that glauconite is common in these sediments.

The succeeding zone of the "Serpulite Grit" points either to a pause in the subsidence or more probably to a slight oscillation which allowed sandy sediment to encroach for a time beyond the "mud-line," and thus to restore the conditions in which the "pipe-rock" was formed. But after this temporary interruption the slow subsidence was once more resumed, as may be inferred from the abundance of dolomitic material towards the top of the zone.

After the deposition of the Serpulite Grit, the stratigraphical chronicle shows that the depression of the sea-floor became more persistent and quicker in pace, and thus that subsidence was considerably more pronounced than deposition. It is true that the few feet of shale which lie at the base of the great "Durness Dolomite" indicate that at that stage in the history the "mud-line" was once more reached, and that a few scattered sand grains are still to be found, even in the lowest beds of the dolomite itself. But the overlying great mass of calcareous and dolomitic sediments, more than 1500 feet in thickness, marks a continuous sinking of the sea-bottom, on which there gathered organic and chemical deposits almost free from terrigenous material. It further shows that this condition of things continued for a prodigiously long period, which, in palæontological chronology, as indicated by the contained organisms, lasted from Lower Cambrian to Lower Silurian (Ordovician) time. The main part of this thick series of deposits appears to be derived from the calcareous and siliceous organisms of the plankton and of the animals that fed upon the rain of these organisms that fell upon the bottom.

The condition of the remains of the larger organisms, as will be described in the next chapter, shows the rate of deposition to have been so slow that both the calcareous and siliceous organisms lay uncovered long enough to be in large measure dissolved before they were entombed in the tardy accumulation of ooze. If this has been the case with the more massive and therefore more resisting organisms, it is tolerably certain that the minuter calcareous forms must have suffered the same fate in a still more marked degree, and thus that the finely-divided calcareous mud which formed the food of most of these creatures would undergo continual dissolution. During this process magnesian salts from the sea-water seem to have been substituted for some of the abstracted calcareous salts, so that the sediments were dolomitised upon the sea-bed itself, or, at least, in such superficial layers as were still accessible to the sea-water. The Cambrian plankton may have contained unicellular calcareous plants, as that of the present ocean does, in which case the small amount of magnesian salts contained in these plants may have been concentrated by the abstraction of the more readily soluble calcareous matter, and thus may have added to the percentage of magnesium carbonate in the dolomites. In some of the zones the alternation of limestones with dolomites may be explained by a more rapid deposition of the former than of the latter. As further evidence of the great amount of solution that took place upon the old sea-floor, numerous layers of detached nodules, and even continuous sheets of chert, can be seen to have been formed in the calcareous muds before their compression and consolidation. Some of these cherts have been found by Dr. George Jennings Hinde to contain sponge spicules, but probably most of the silica was obtained from more simply organised minute animals and plants of the plankton. The oolitic structures which occur in some of the limestones are at times replaced by chert.

CHAPTER XXIII.

PALÆONTOLOGY OF THE CAMBRIAN SYSTEM IN THE NORTH-WEST HIGHLANDS.*

In the present chapter an account will be given of the organic remains which have been obtained from the several subdivisions of the Cambrian series in stratigraphical order, beginning with the oldest members.

LOWER CAMBRIAN.

Lower and Upper Quartzite.

In the lower quartzite organic remains are so rare that they have been met with only at one place. They consist of the cylinders of sand known as "pipes," and named *Scolithus linearis* (Haldeman). These are attributable to burrowing annelides, and they not only indicate the presence of such animals during the deposition of the quartzite, but also of sufficient organic matter having been mixed with the sand where they occur to furnish nourishment to the worms.

In the upper zone of the quartzite these cylinders become so numerous as to have gained for it the title of "The Pipe-rock." But, besides their great abundance, they vary so much in form and mode of occurrence (probably indicating that they were produced by different species of annelides) that different forms of them appear in a definite chronological order. Hence successive sub-zones of the "pipe-rock" have been mapped out by means of them.

The beds of the lowest sub-zone (I.) are characterised by "small pipes," about one-eighth of an inch in diameter, which pass up through the somewhat massive beds of white or pinkish granular quartzite at right angles to the bedding planes, and end on the upper surface of the beds in small cup-shaped hollows, from a quarter to half an inch across the mouth.

In Sub-zone II. the "ordinary pipes" are larger, often reaching half an inch in diameter, while those of the underlying zone disappear.

Sub-zone III. is characterised by "trumpet pipes," the *Arenicolites* of Salter. In these the cylinders, when followed to the surface of the bed, are found to end at the bottom of cup-shaped depressions, which sometimes measure two inches across. Seen in section, the cylinder can be observed to stand up a little into the bottom of the cup, while the layers of the quartzite, which are comparatively thin in this sub-zone, are attenuated and

* By B. N. Peach.

bent downwards as they approach the cylinder in such a manner as to suggest the operations of a worm, plentifully provided with chetæ, which left the voided cylinder behind as it sank down into its burrow. An inverted cone-within-cone structure is thus produced, simulating that of a primitive orthoceratite, for which, indeed, these relics were at first mistaken. Two forms of "trumpet pipes," a larger and a smaller, are distinguishable in the field, sometimes associated together and sometimes separately. These trumpet pipes do not occur in all the beds of the sub-zone; but the ordinary "pipes," like those of Sub-zone II., are to be found throughout the zone, and are by far the most abundant. In addition to these worm-casts, a small hollow conical calcareous fossil, named *Serpulites Maccullochii* by Salter after its first discoverer, and now supposed to belong to the tubicolar annelides, was found by Mr. H. M. Cadell in the rocks at the top of this sub-zone in the Reay Forest, near Loch Stack, in Sutherlandshire. This fossil is found associated with *Olenellus* on a higher horizon; the genus is characteristic of the Lower Cambrian rocks.

In Sub-zone IV. only the ordinary "pipes," like those of the lower zones, occur, but they are exceedingly numerous and conspicuous, owing to several concurring circumstances. The strata are thinly bedded, and the bands are usually of red and white colour in rapid alternation, while the "pipes" are usually wholly white. The dragging downwards and attenuation of the layers as they approach the cylinder is also very conspicuous at all depths, a circumstance which, together with the cup-shaped depressions, proved to be of great service in distinguishing whether the beds are in their natural order or inverted in those areas in which the rocks have been greatly disturbed.

Sub-zone V.—The pipes are here somewhat larger in diameter than those of the underlying sub-zones, but they are otherwise of the ordinary type. As the beds are massive and the grains large and well rounded, the rock is often comparatively uncompacted and less of a quartzite than the others. Its general colour if often red or purple, while the pipes in it are white. Sometimes the matrix is discoloured or bleached for a short distance round the pipes. A similar decolouration takes place round the burrows of the recent lobworms on our shores. One bed, which lies at the very top of the quartzite, and which probably belongs more properly to the overlying fucoid-beds, as it is mixed with a good deal of shaly material, contains "pipes" measuring sometimes nearly an inch across.

In America *Scolithus linearis* occurs in Cambrian rocks chiefly in connection with the *Olenellus* zone.

"*Fucoid Beds.*"

In this zone *Scolithus* continues to occur, but the most characteristic worm casts are those which lie along the bedding planes of the shales, and are known under the name of *Planolites*

(Nicholson). It is these flattened casts that have been mistaken for the remains of fucoids, and from which the name of the zone has been derived. Where alternations of sandy and shaly strata occur, abundant evidence is procurable that these casts, as well as those known as *Scolithus*, were made by some worm-like animal, which brought up the sand of the casts from beds underlying the shales in which they actually occur. They cannot, therefore, have been formed by sand filling in the burrows from above. In addition to these annelides, the muds and calcareous sediments of this zone appear to have been so well fertilised by the plankton as to support several other organisms. Among these, certain forms, which are individually abundant, have been mistakenly classed among the pteropods, but may with more reason be regarded as tubicolar annelides. They belong to the genera *Salterella*, of which three specimens are represented, and *Coleolides*, represented by a single species. Two species of *Hyolithes* also occur, an organism which probably links the worms with the hingeless brachiopods. Boring annelides also appear to have made sinuous tunnels in the thickened portions of the dead or discarded tests of trilobites.

Echinoderms are represented by some minute fragments showing the microscopical structure of their plates and ossicles, which, together with debris of shells and trilobites, form nuclei round which pisolitic structures have been built up in certain dolomitic bands. The original carbonates in these beds have in some cases been replaced by iron-ores, as is observed in specimens from certain bands first discovered by Mr. Horne in the Achnashellach Forest, which Mr. Teall has found to present characters similar to those of some ironstones that have replaced Carboniferous limestones in Wales and Cumberland. The echinodermal remains are provisionally referred to the genus *Eocystites* (Billings.)

Brachiopods are represented by the hingeless forms *Paterina* (*Kutorgina*) *labradorica* and *Acrothele subsidua*, the former being one of the simplest and most primitive known types, representing an early stage in the development of all the higher forms. Both of these species are found in the *Olenellus*-zone of America, the former in Newfoundland and Canada, the latter occurring plentifully with *Olenellus Gilberti* at Pioche, Nevada, and in association with Middle Cambrian fossils at Antelope Springs.

Gasteropods are represented by a badly-preserved form, probably a *Murchisonia*, found near Tokavaig, in Skye, and by *Helenia bella*, a curved tube open at both ends, doubtfully referred by Walcott to the *Dentalidae*. This organism also occurs together with *Holmia* (*Olenellus*) *Broggeri*, at Manuels Brook, Conception Bay, Newfoundland. Arthropods are represented by *Aristozoe rotundata*, and a species of *Nothozoe*, among the *Phyllocaridea*, which are also met with in the *Olenellus* zone of America.

The trilobites, however, are the most characteristic feature of this horizon in the Cambrian series. The genus *Olenellus* of Hall is here represented by five species and varieties closely allied to *O. Thomsoni* and *O. Gilberti*, the forms which mark the

Georgian Terrane or *Olenellus*-zone on the east and west side of North America respectively. The genus *Olenelloides* was made to hold a primitive trilobite in almost vermiform aspect, highly armed with spines, and resembling larval stages of *Olenellus*, but evidently in adult condition. The same genus appears also abundantly in certain dolomitic beds along with *Olenellus*. A small fragment of trilobite, which suggests close affinities with *Conocoryphe*, has likewise been found, but in too imperfect a state to allow of a determination to which of the sub-genera it should be assigned. With the exception of one or two forms which have only as yet been found in the North-West Highlands, the whole assemblage of fossils from the Fucoid-beds of Sutherland, Ross, and Skye is almost identical with that found in the *Olenellus*-zone of North America.

"*Serpulite Grit.*"

In this zone worm-casts of the nature of *Scolithus* form still a characteristic feature. They are of various kinds, the most conspicuous being "pipes," which sometimes attain a diameter of nearly an inch. These can be traced through the rock vertically for a length of more than a yard, until they end on the upper carious weathering surface of the grit in cup-shaped depressions measuring several inches across. These pipes are sometimes contracted at regular intervals in such a manner as to suggest that the contractions are due to the peristaltic action of the intestine of the worm. Sometimes the part between the "pipe" and the surrounding matrix has been filled in with sand containing more carbonate than either of them, so that on a weathered face of the rock the "pipe" is seen in the middle of a hollow tube. Smaller pipes, which in one layer appear to be more calcareous than the matrix of the bed, may be observed to have weathered out so as to leave the rock honey-combed with their hollow casts. The small tubicolar *Salterella*, the *Serpulites Macullochii* of Salter, first discovered by Macculloch from this band, to which it gives the name, occurs in myriads in certain layers, and is usually to be found scattered more or less throughout the whole of the zone.

Of higher organisms in the Serpulite Grit, the head shield of *Olenellus Lapworthi* was found in the Dundonnell Forest, and an orthoceratite is said to have been obtained at Eireboll in Sutherlandshire. Professor Lapworth records the finding of *Orthoceras* and Linguloid shells (?) in the dolomitic carious-weathering beds at the top of the zone in Eireboll, but he regards them as the basement beds of the Durness Limestone.*

The Durness Limestone or Dolomite.

Grudhaidh Group (in part).

The first 30 feet of this sub-division of the Durness Dolomite are here claimed to belong to the Lower Cambrian or *Olenellus*-

* *Geol. Mag.*, vol. x., new ser., p. 126, 1883.

zone, because of the occurrence in them of two thin but remarkably persistent layers which are usually crowded with two species of *Salterella* (*S. rugosa* and *S. pulchella*), forms also found in the *Olenellus*-zone of America. One of these layers lies immediately above a few feet or inches of a dark carbonaceous shaly limestone which forms the base of the Durness Dolomite, and in which *Salterella* is also occasionally found. The other layer is met with about 30 feet further up. Besides the fossils just mentioned, worm-casts (*Planolites*) also occur, but less abundantly than in some of the higher layers of the sub-division.

From the palæontological evidence which has now been stated, it may be concluded that the groups of strata from the middle of the "Pipe-rock" up to the top of the first thirty feet of the Grudhaidh Dolomite should be classed as Lower Cambrian, seeing that they enclose a fauna identical with that of the *Olenellus*-zone so well developed in North America. How much more of the rest of the Durness Dolomite may belong to the same sub-division cannot be determined owing to the paucity or absence of organic remains. As to the quartzite beneath the trumpet pipes (Subzone III. of the "Pipe-rock"), though no other fossil evidence beyond the occurrence in it of *Scolithus linearis* has hitherto been forthcoming, yet, for the sake of convenience, all the sub-zones down to the base are provisionally regarded by the Geological Survey as part of the Lower Cambrian series.

From the study of the fossils of the Durness Limestone, Salter pointed out, as early as 1859, that the biological affinities are more closely linked with American than with European forms, and all subsequent observation has confirmed his opinion. This curious relationship, so distinctly traceable among the fossils of the Lower Cambrian zones of the North-West Highlands, continues to be visible in the rest of the Cambrian succession of that region. Not only are the fossils identical on the two sides of the Atlantic, but the sediments in which they have been preserved present a remarkable similarity, as if the North American and Scottish Cambrian rocks were deposited under similar, if not identical, physical conditions, and as part of one and the same geological and zoological province.

Middle and Upper Cambrian.

Durness Dolomite.

I. Grudhaidh Group.

The portion of this group which overlies the upper *Salterella*-bearing band above described, in the absence of definite fossil evidence, is here included in the Middle Cambrian series. It consists in great part of mottled dolomite, the mottling being due to the great abundance of worm-casts of the nature of *Planolites* A conspicuous band with oolitic structure lies about the middle of the group. In this band, while the oolitic grains are generally calcite or dolomite, in one seam they may often be seen to have been preserved in silica, which has probably replaced the original carbonate. Thin slices of both these types of oolite have been prepared and microscopically examined, but no organic structures have been observed in them. In Assynt one of the uppermost beds of the group displays worm-casts, which have sometimes been replaced by silica. With the exception of *Planolites*, no fossils have as yet been obtained from this part of the series of strata, and as by far the greater part of the rocks of the group show evidence that their component materials passed through the digestive system of worm-like creatures, they must have once been in the state of a finely-divided calcareous mud or sand, which was probably derived from both the calcareous and siliceous organisms of the plankton.

II. Eilean Dubh Group.

The only fossils obtained from this group are of the nature of worm-casts, which, in marked contrast to the other sub-zones, are few in number and confined to one or two beds. This paucity may be due to the original absence of calcareous organisms larger than those which constituted the greater part of the plankton, for though the component strata of the group are everywhere more or less magnesian and often dolomitic, yet they always present a fine-grained and thinly-bedded character, indicating that their original condition was that of fine mud. If any larger forms contributed to the substance of the rock, they appear to have been reduced to a fine calcareous powder.

A close examination of the strata in the field has disclosed the interesting fact that some of them have here and there "set" or solidified on the sea-floor, and have afterwards, while the deposition of the series was still going on, been broken up in places or brecciated, the interstices being filled in with a matrix of similar composition to the dislocated layers, while the overlying and underlying sediments have been undisturbed.

Siliceous organisms seem to have contributed to the building up of this group, for in the Assynt region layers of chert nodules have been found on several horizons, and also continuous layers of chert, some of which attain a thickness of more than two feet. Oolitic structures appear in the cherts of this group in Skye. These have been cut and submitted to Dr. G. J. Hinde for microscopic examination, but he was unable to detect any undoubted organic structures in them. The cherts from this group are less granular in texture than those which have replaced the calcite of the oolites of the Grudhaidh Group.

III. Sail Mhor Group.

This group consists of coarsely-granular dolomites charged with worm-castings, which are often of a different colour from the matrix, so as to have earned for it such names as "The Mottled Group" and "Leopard Stone," the latter being that by which it is locally known. That siliceous organisms contributed material towards the building up of this group of strata also, is indicated by large nodules of chert which occur plentifully along certain layers near the base. Some of these resemble the "Paramoudras" of the chalk in being arranged vertically above each other. It is clear that the silica replaced the calcareous mud which constituted the limestone before its compression and consolidation, for the lines dividing the layers are seen to run continuously into the chert from the limestone, while thin layers extend from the limestone and penetrate into the edges of the siliceous nodules. The silica became consolidated into chert prior to the compression of the calcareous mud through the weight of the accumulating sediment, so that the part of each layer now represented by chert is much thicker than that still represented by limestone. Certain siliceous hollow rods in this group may possibly be remains of sponges, like the *Rhabdaria* of Billings, which possibly contributed to the formation of the nodules. But the greater proportion of the silica was probably derived from the plankton, and most probably from diatoms, as unicellular plants doubtless formed the chief support of the oceanic animal life during the Cambrian period as they do at the present time. Radiolaria may likewise have shared in the formation of the chert; they are certainly among the oldest fossils known. The opinion that the limestone mud was not a mere chemical precipitate from sea-water, but a kind of organic calcareous ooze, is perhaps strengthened by the fact that when the calcareous rocks of this group are broken they emit a strongly fetid odour, and when dissolved leave a residue of carbon. The researches of Dr. G. J. Hinde have shown that cherts examined by him from nearly all the great geological formations from all parts of the globe have had an organic origin. A strong presumption is thus raised that most of the cherts in sedimentary rocks have been produced from organic silica.

Calcareous organisms larger than could be provided by the plankton also occur as fossils in this group, preserved in the form of calcite, but they are few in number. Many more may have once existed, but, if so, they have been destroyed during the process of dolomitisation and the production of the coarsely crystalline texture which characterises the rocks of the group. The gasteropods are represented by a single specimen of *Murchisonia*, not sufficiently well preserved for specific identification, and by two species of *Pleurotomaria* (*P. Ramsayi* and *P. Etna*) of a type found in the "Calciferous" rocks of Newfoundland and Mingan Islands in Canada. The former presence of cephalopods is proved by the occurrence of at least two forms probably belonging to different species, with oval section, slight curve of the cone, closely-set septa, and wide endogastric siphuncles. These have been provisionally placed in the genus *Cyrtoceras*, though they seem to have strong affinities with such primitive types as *Endoceras* and *Piloceras*. The arthropods are represented by part of the epistome of a large asaphoid trilobite which is almost identical with that of *Asaphus canalis* (Conrad), a fossil of the Calciferous horizon of Newfoundland. Thus the evidence of the fossils, scanty and imperfect though it be, shows a strongly-marked American facies in the fauna of this group.

IV. Sangomore Group.

This group is composed chiefly of granular dolomite, but towards the top one or two thin bands of fine-grained limestone make their appearance in the Durness district. Bands of chert also occur chiefly towards the base of the group, one of which at Durness is 5 feet thick. Some of the beds are oolitic, and in one case the oolites are preserved in crypto-crystalline silica, but no organic structures have been observed in them. No fossils have been found. Their absence from the dolomites, which are more coarsely crystalline in this than the two preceding groups, might be accounted for by the amount of reconstruction which the rocks have undergone, but this explanation would not hold for the fine-grained limestones, from which fossils are also absent.

V. Balnakiel Group.

This group consists of alternations of dark and lighter coloured fine-grained limestones not much marked by worm-tracks, including nodules and thin bands of black chert. This association of sediment points to the still-continued deposition of minute calcareous and siliceous organisms. A few of the beds only have been dolomitised. Some of the limestones are highly fossiliferous, and it is from this and the overlying group that most of the fossils of the Cambrian series of the North-West Highlands have been obtained. As these organisms are for the most part common to the two groups, the whole fauna will here be treated as one.

VI. Croisaphuill Group.

The rocks of this group are much more varied than those of the preceding one. Towards the base they consist chiefly of massive beds of dark-grey limestone, full of worm-casts, which are now chiefly represented by dolomite, so that they stand out in matted masses on the weathered surface of the rock, the limestone matrix having yielded to solution more readily than the dolomite. Such rocks are highly fossiliferous, but where bands of granular dolomite make their appearance fossils are rarely or never met with. The lower part of the group is marked by several layers of small chert nodules. The middle portion is made up chiefly of unfossiliferous granular leaden-coloured dolomite, with a few light-coloured bands of fossiliferous limestone full of worm-casts. The upper part, consisting of massive sheets of fossiliferous limestone full of worm-casts preserved in dolomite, resembles the lower sub-division.

Thus up to the very top of the Cambrian series of Sutherland and Ross impressive evidence is supplied by the abundance of worm-casts that the rocks must have accumulated in the state of fine mud or ooze, probably mainly derived from the minute organisms of the plankton. The fact that the worm-casts in the two upper groups of the series are for the most part preserved in dolomite, while the matrix remains a limestone, suggests that either the worms were selective as to their food or that their gastric juices had the effect of predisposing the casts to be dolomitised under the influence of magnesian solutions more readily than the surrounding mud.

The fossils now to be more specially noticed are usually preserved in orbicular silica and filled in with calcite, and their microscopic structure has been entirely obliterated. They are, moreover, generally incomplete and seldom show their external markings—a condition probably referable chiefly to decomposition, solution, and disintegration prior to their being embedded. That their imperfection cannot be attributed to actual abrasion on the sea-floor appears to be placed beyond doubt by the condition of some of the fossils. Thus the valves of lamellibranchs are often found attached and in the position in which the shell lived, though part of the organism has been removed, obviously through solution. In most cases the septa and walls of chambered shells have been wholly or in part dissolved away, so as to leave only the more massive structures of the siphuncles, and worm-castings are often found within the chambers where the septa have been preserved. These features seem to indicate that the accumulation of the calcareous mud in which the fossils were embedded was so slow that there was time for the solution of part of an organism before the whole of it was covered up. Indeed, there is good reason to believe that a great many organisms totally disappeared by this process, for in some of the layers of the Croisaphuill group near Durness the massive opercula of certain species of *Maclurea* occur in abundance, while the shells belonging to them have not been observed.

Siliceous sponges are represented in the two uppermost Cambrian groups by the genera *Archæoscyphia* (Hinde) and *Calathium* (Billings), and by the doubtful forms *Rhabdaria* and *Trichospongia* of Billings. These fossils present no exception to the rule that the organisms were imperfect before they were covered over with succeeding sediments. Only fragments have been preserved, and usually those parts lying towards the base of the forms. Moreover, after being embedded, the original silica of the spicules has been removed, and the structures have been filled in with orbicular silica and calcite, so that the microscopic structure of the organisms is now quite obliterated. The abstracted silica may have furnished some of the chert of the nodules, as Dr. Hinde found remains of sponges in some of the nodules from this horizon at Durness. Most of the species of *Archæoscyphia* and *Calathium* are found in the "Calciferous" rocks of Newfoundland and Canada, where they are associated with *Rhabdaria* and *Trichospongia*.

Only one specimen of what appears to be a coral has as yet been observed, but it is not sufficiently well preserved even for generic identification.

Hinged brachiopods are represented by *Camarella antiquata* (Bill.), and *Orthisina festinata* (Billings), which occur in the *Olenellus*-zone of America; likewise *O. grandaeva* (Bill.), a "Calciferous" form found in Canada, and *O.* (*Orthis*) *striatula* (Hall), also an American form.

The only lamellibranchs that have been found belong to the genus *Euchasma* of Billings, a form allied to *Conocardium*. In addition to his *E. Blumenbachii*, which he obtained from the "Calciferous" rocks of Newfoundland and from the Mingan Islands, several varieties have been met with in the two uppermost groups of the Durness Limestone, which link that genus by almost insensible degrees to his genus *Eopteria*, founded on a form obtained from beds of the Quebec group at Port au Choix, Newfoundland. Billings, however, recognised the near relationship of the two genera, and was doubtful if *Eopteria* would stand as an independent genus.

Gasteropods are perhaps the most characteristic and abundant members of the fauna of the two uppermost groups. The peculiar primitive euomphalid genera *Maclurea* (Lesueur), and *Ophileta* (Vanuxem), are especially prominent. The first-named genus is represented by at least five species, which can be identified from the remains of the shells themselves. Four of them are the most common shells of certain sub-zones of the Calciferous rocks of Newfoundland and Canada, while a fifth, *M. Peachi*, has as yet been found only at Durness and Skye, though opercula almost identical with those of this species are figured by Billings, and are said to occur together with some of the other species above referred to at Cape Norman in Newfoundland.* Besides the operculum of *M. Peachi*, four other distinct forms of opercula are also present. These range from flat types like that of *Maclurea matutina* (Hall), figured by Billings,† through those like *M. Peachi*, figured by Salter, to highly elongated and slipper-shaped species, with only a very slight spiral curve. These different types do not occur at random throughout the two groups of strata, but each seems to be restricted to particular beds, where it occurs in profusion. There appears, therefore, to be a probability that these rocks could be subdivided into distinct palæontological zones by means of these and other fossils, though the task has not been attempted by the Geological Survey. Several species of *Ophileta* occur besides the *O. compacta* of Salter. Some of these can be identified with species found in the Calciferous rocks of Newfoundland, while one at least appears to be new to science. Two species of whorled shells, loosely coiled in a flat spiral, have been

* *Geology of Canada* (Palæontology), Vol. I., p. 243, fig. 228, 1861–1865.
† *Geology of Canada*, p. 115, fig. 24, 1863.

provisionally placed in the genus *Euomphalus*, while several forms belonging to an allied family, the *Turbinidae*, have been classed with the genus *Oriostoma* (Lindström) (*Omphalotrochus*, Meek). One of these, *O.* (*Pleurotomaria*) *Calphurnia* of Billings, is met with in the rocks of the Quebec group of Cape Norman. Three other species, nearly related to it, and which can be connected with it by intermediate forms, also occur. It is an interesting and highly suggestive fact that hemispherical bodies, preserved in orbicular silica, appear in numbers on the same slabs of stone with many of these fossils. One of these bodies was actually found lying at the mouth of a shell in such a manner as to suggest that it is the operculum. If this suggestion be confirmed, it would point to the inference that we are dealing here with primitive types possessing massive calcareous opercula. In the case of *Maclurea*, no great stretch of the imagination is needed to conceive that this form may not be far removed from an actual bivalve shell.

The genus *Murchisonia* is represented by fourteen species and varieties, which exhibit a great range in form. These have been divided into two sub-genera. Those forms having beaded whorls and simple slit-band form the sub-genus *Hormotoma*; those with sharp spiral keels are included in the sub-genus *Ectomaria*. Under the first group or *Hormotoma* sub-division come *M.* (*H.*) *angulocincta*, *M.* (*H.*) *Anna*, *M.* (*H.*) *Artemesia*, *M.* (*H.*) *Augustina*, *M.* (*H.*) *linearis*, which are likewise found in the Calciferous rocks of Canada and Newfoundland; also *M.* (*H.*) *bellicincta* and *M.* (*H.*) *gracilis*, which are common forms in the Black River and Trenton groups of America, or the equivalents of the Llandeilo and base of the Bala rocks of Britain. In addition to these species, *M.* (*H.*) *antiqua* and *M.* (*H.*) *gracillima* are as yet only known from the Durness Dolomites.

Of the *Ectomaria* sub-division, *M.* (*E.*) *Adelina* is found in America in the Calciferous group, while *M.* (*E.*) *pagoda* is a Black River form, of which two varieties have been described by Miss Donald from specimens collected at Durness and in Skye. Another form of *Murchisonia* has been met with belonging to a different group, and nearly related to *M. Milleri* (Rogers), which was wrongly named by Hall *M. bicincta*. It appears in the Trenton and Hudson River group of America.

A corresponding variation is found to exist in the species of the genus *Pleurotomaria* preserved in the Balnakiel and Croisaphuill groups of strata. One type has the same characteristics as *Hormotoma*, except that the cone increases more rapidly, in consequence of which the spire is shorter. In fact, these *Murchisonias* and *Pleurotomarias* merge so insensibly into one another that any line drawn between the two genera must be an arbitrary one. Among the forms of *Pleurotomaria* resembling *Hormotoma* a large turgid species has been obtained. Examples of the same type have been found in the Calciferous rocks of Canada and in the Trenton Limestone. A small form, which has been doubtfully placed with *P. gregaria*, also occurs in Durness and Skye, as well as in the Calciferous rocks of the Mingan Islands of Canada.

A second series of the type of *P. calcifera* of Billings, with almost flat spiral and wide umbilicus and of lenticular section like *Raphistoma*, also appears in the Scottish Cambrian fauna. Besides *P. calcifera*, this fauna likewise includes *P. canadensis* and *P. laurentina*, all of which are found in the Calciferous rocks of Canada. This type of shell merges into another in which the spire is higher, giving a trochiform appearance; the umbilicus is wide, and the section of the whorl rhomboidal. The typical species of this group is *P. Etna* (Billings). It is associated with *P. Ramsayi*, and both these species are fossils of the Calciferous rocks of Newfoundland and Canada. *P. Thule*, the species described by Salter from the Balnakiel group at Durness, belongs to this group. Fragments of a large unnamed shell also of the same type is plentiful at Durness. Two other forms, *P. Dryope* (Bill.) and *P.* (*Helicotoma*) *spinosa* (Salter), which appear in the two uppermost groups of the Cambrian formations of the North-West Highlands, are also present in the Black River Limestone on the horizon of the Llandeilo Limestone of Wales.

The cephalopods of the two uppermost groups in the Sutherland succession of strata are of almost equal interest with the gasteropods. They are all of a primitive type, and display a considerable range in form. The characteristic feature of the orthoceratites is the relatively large size of the siphuncle, which is usually supplied with endocones and organic deposits, and is placed laterally. The most conspicuous species in this respect belong to the genus *Piloceras*, which was founded by Salter* upon the invaginated siphuncles obtained by Charles Peach from these two groups at Durness. This determination was formed under the belief that the fossils constituted the complete shells of a very primitive form of orthoceratite, in which what are now known to be the invaginated endocones were supposed to represent both septa and siphuncle. More complete forms, showing the relation of this complex siphuncle to the septa and outer walls, were subsequently found in America and described by Whiteaves†, Billings‡, and Sir J. W. Dawson¶. Amongst the earlier collections made by the Geological Survey, though most of the specimens consist of the siphuncle only, there are several specimens which show this relation, and which were studied and used by A. H. Foord§ for the purposes of the British Museum *Catalogue of the Cephalopods*, where some of them are figured. The collections made by the Geological Survey in later years have furnished many more specimens, which prove that, besides the form named by Salter *Piloceras invaginatum*, several others are

* Salter, *Quart. Journ. Geol. Soc.*, vol. xxv., 1859, p. 376.

† Whiteaves, *Bull. Amer. Mus. Nat. Hist.*, vol. i., No. 8, p. 323, pl. xviii. (New York), 1896.

‡ Billings, *Geol. of Canada*, Palæ. Foss., vol. i., pp. 256-258, fig. 240 (1861-1865).

§ Foord, *Cat. Foss. Ceph. Brit. Mus.*, pt. i., figs. 17, 18, 19 (1888).

¶ Dawson, *Canadian Naturalist*, New. Ser., vol. x., No. 1.

represented. These differ from that type in the taper and curve of the siphuncle, in the relative distances of the septa from each other, in the obliquity of the ridges left on the outside of the siphuncle where it is clasped by the septa owing to its being always placed laterally on the concave or gastric side of the cone. Two specimens show a long slit at one side of the invaginated funnel-shaped sheath. The genus *Piloceras* has been recorded from the North-West of Scotland, Canada, and the Eastern States of America only. Four species are found in the Calciferous group of Newfoundland, one in the equivalent rocks of Lachute, near Montreal, and the sixth occurs in the "Bird's Eye" Limestone of Fort Cassin, Vermont, in strata on the horizon of the Lower Llandeilo of Wales.

The allied genus *Endoceras* (Hall) is represented in the North-West Highlands by several forms, but owing probably to the causes already mentioned, for the most part only siphuncles have been preserved, and even these are in a very fragmentary condition. One specimen, in which the outer walls and septa are preserved, shows a gently-tapering smooth cone more than one foot in length, having the septa set at moderate distances from each other, with a large laterally-placed siphuncle which shows organic deposits. Another fragmentary specimen has retained a small portion of the smooth outer wall and a wide, gently-tapering siphuncle with endocone, the siphuncle being almost in touch with the outer wall of the cone. All the detached siphuncles agree in one respect: they exhibit marked obliquely-set annulations on their exterior where the successive septa have merged into the siphuncle, and where in consequence the material of the siphuncle-wall, having been thickened, has longer resisted the dissolving agents than the thin septa. Most of them show endocones, and in one case the intermediate organic deposits between the outer and inner cones appear to simulate septa. Several of the siphuncles closely resemble the corresponding structures of forms found in the Calciferous rocks of Canada, and described and figured by Billings under the names of *Orthoceras Becki*, *O.* —— ? *O. Montrealense*, and *O. sordidum*.* Numerous species of *Endoceras* occur in the "Orthoceras Limestone" of Sweden, which immediately overlies the *Phyllograptus* shales that represent the horizon of the Arenig rocks of Britain.

Certain forms placed by Salter in the genus *Orthoceras* appear in the two uppermost groups of Durness and in Skye. The most common and also the most marked species, *Orthoceras mendax* (Salter), is moderately tapering, strongly annulated, circular in section, with moderately-arched septa and sub-central siphuncle, which measures about one-third of the whole diameter. According to Blake,† the siphuncle shows a central sheath and organic deposits. This form is doubtfully referred by Foord ‡ to *Actinoceras*. From the consideration of these facts, it appears

* *Geology of Canada*, p. 121, figs. 35-37 (1863).

†Blake, *Brit. Foss. Ceph.*, pt. i., p. 81, pl. iii., fig. i.

‡ Foord, *Brit. Mus. Cat. Ceph.*, pt. i., pp. 166-167.

to have close affinities with *Endoceras*. Two species, *O. Priamus** and *O. Lamarcki*, from the Calciferous rocks of Newfoundland and Canada, figured and described by Billings,† are so much like *O. mendax* in their rate of taper, in their annulations, in their septa, and in the size and position of their siphuncle, that they are evidently nearly allied to that species, if not actually varieties of it. The species figured by Salter from the Durness Limestone as *O. vertebrale* of Hall‡ has been shown by Blake§ to belong to *O. mendax* (Salter). The only form that seems really to belong to the genus *Orthoceras* is the *O. pertinens* (Blake), which occurs in both the stratigraphical groups of Durness and also in Skye.

A small fragment, which shows the interior of a siphuncle and a few septa, may possibly belong to a species of the genus *Actinoceras*. It was found in the Balnakiel limestone at Durness.

Several slightly-curved forms with elliptical section and closely-set septa from the two uppermost groups of strata have been provisionally placed in the genus *Cyrtoceras*. The variation in form, as well as the position of the siphuncles in these fossils, show them to belong to several species, though the specimens are all too imperfect for specific identification. The siphuncles are placed close to the side, and usually on the concave or endogastric, but sometimes on the opposite, side. They are wide, and, like most of the forms, they taper rapidly. Although no endocones have been observed, probably owing to the prevalent manner of entombment and preservation, the whole form as well as the large siphuncles bear close resemblance to *Piloceras*. It is evidently a form of the type figured by Salter as doubtfully belonging to the genus *Oncoceras*.|| Similar forms are abundant in the rocks at Point Levis, near Quebec.

Whorled nautiloids are represented by fragmentary remains of several distinct forms, in which the cone shows a very gentle taper and the folds are slightly impressed on one another, so as to present a reniform section. All the specimens in which the exterior is seen show strong ribs. The septa are moderately arched, and in some are closely-set, while in others they stand moderately far apart. The siphuncles, compared with those of the straight and slightly-curved nautiloids in the same strata, are narrow and are placed sub-centrally, usually nearer to the gastric than to the dorsal side, though in the outer whorls the opposite arrangement may sometimes be noticed. The specimens have been too badly preserved for specific determination, but fragmentary though they be, they seem to belong to the genus *Trocholites* of Conrad. Nautiloids of this type, placed in the genus *Nautilus* by Billings, occur in Newfoundland and Canada in the Calciferous sand-rock, associated with an assemblage of

* Billings, *Palæozoic Foss. Canada*, p. 253, fig. 239.
† *Ibid.*, *Op. cit.*, pp. 255, 347, fig. 336.
‡ Salter, *Quart. Journ. Geol. Soc.*, vol. xv., p. 375, pl. xiii., figs. 22, 23.
§ Blake, *Brit. Foss. Ceph.*, pt. i., p. 82.
|| *Quart. Journ. Geol. Soc.*, vol. xv., p. 375, pl. xiii., 1859.

fossils similar to that which is found in the two uppermost groups of strata now under consideration in Durness and Skye.

Trilobite remains are extremely scarce in these two groups of the Durness Dolomite, and even when found are so fragmentary and poorly preserved that they can rarely be specifically or even generically identified. Only one species, *Bathyurus Nero* (Billings) has been with certainty determined. It is represented by two detached glabellæ, two separate free cheeks, and a pygidium. This form is found in Newfoundland in the Calciferous formation, where it ranges from Beds F to N of Billings' table.* Two pygidea of a trilobite nearly allied to the above also occur in the collection from these zones at Durness.

In the collection made in Skye, a glabella of a trilobite probably belongs to the genus *Solenopleura*. It strongly resembles the corresponding part of *S. tumida* (Wallcott), a form found in the *Olenellus*-zone of America.

Two badly-preserved trunks of a trilobite have been found, showing strongly-marked central axis, with pleura well-grooved and facetted and sharply bent downwards from the fulcra, the distal portions being directed backwards in the anterior segments, and placed either at right angles to the axis or bent slightly forward in the hinder ones. One of the specimens presents 13 free segments, while in the other 14 can be counted. The latter exhibits also the pygidium, which is partially detached and only partly exposed. The central axis, however, shows it to be made up of at least four coalescent segments. The specimen also displays the general form of the glabella and a distended cheek, but these parts are in even a worse state of preservation than the rest of the specimen. The form closely resembles some species of *Conocoryphe*, and comes near to the *C.* (*Conocephalites*) *Schulzeri* of Schlotheim.

In another specimen the part of a trunk of a trilobite, which is preserved in chert, possesses a well-marked central axis and grooved pleura on the left side, but the distal portions beyond the fulcra have not been preserved, neither are the pleura of the right side to be seen, except close up to the central axis. The form is only slightly arched. Sixteen free segments can be counted in the fragment. From its very gentle taper, indicated by the lines made by the edge of the central axis and by the row of fulcra being almost parallel, also from the fact that a gap occurs in the series between the most anterior segments and the rest, where the specimen is in a bad state of preservation, the whole trunk may almost certainly be regarded as having originally had more segments than are now to be seen. Such a fragment raises a strong presumption that it belongs to the genus *Paradoxides*.

The only other trilobite remains consist of two large plain glabellæ, without furrows and with large nuchal spines. One of them measures more than an inch in length by nearly as much in breadth. The other is about half an inch long, while the

* Billings, *Pal. Foss. Canada*, pp. 366-372.

spine, which is broken, is quite as long as the glabella, is hollow and oval in section, the long axis of the oval being at right angles to the plane of the body. This type of glabella is found in the genera *Agraulos*, *Zacanthoides*, *Solenopleura*, *Dorypyge*, and other Middle and Upper Cambrian trilobites.

Thus the whole facies of the trilobites is strongly Cambrian. The horizon of the Balnakiel and Croisaphuill groups is plainly indicated by the fossil evidence to be identical with the strata in Newfoundland from I to N of Billings' table which underlie the dark shales of Table Head, Pistolet Bay, and Cow Head. At the latter locality these shales have yielded an abundant graptolite fauna characteristic of the Arenig rocks.

VII. Durine Group.

The highest zone of the Durness Limestone is only found at Durness. It consists of grey limestone and chert. The only fossils yet obtained from it are *Murchisonia* (Hormotoma) *gracilis* (Hall) and *M.* (*H.*) *gracillima* (Salter). *M. gracilis* is common in the Black River Limestone at Pawquette Rapids, River Ottowa, Canada, which is considered to represent the horizon of the Llandeilo Limestone of Wales. These fossils do not, however, suffice to fix the stratigraphical position of the present group, for they appear abundantly in the underlying Balnakiel and Croisaphuill groups both at Durness and in Skye.

From the palæontological evidence obtained from the Durness dolomites and limestones which has now been stated, it appears that all the calcareous beds, overlying the *Salterella* dolomites (Lower Cambrian), represent the Middle and Upper Cambrian formations. But owing to the American facies of the fauna it is impossible to correlate the sub-divisions either with the Welsh or Scandinavian succession.

CHAPTER XXIV.

THE CAMBRIAN STRATA FROM DURNESS AND EIREBOLL TO LOCH MORE.*

1. *Durness Outlier.*

The Cambrian strata of Durness cover a triangular area about fourteen square miles in extent, of which about nine square miles are occupied by the dolomites and limestones of the Calcareous Series. The apex of this tract lies in Strath Dionard, about nine miles south-west of Durness village, and its base stretches along the north coast from the Kyle to Sangobeag. As shown on Sheet 114, this arrangement is due to powerful faults. Along their eastern margin the beds are completely separated from the members of the Cambrian system at Eireboll, with which they were at one time united, by a north-east and south-west dislocation that brings them in contact with the Lewisian gneiss. On part of their western boundary also they are truncated by a fault that lets down the Basal Quartzites and Pipe-rock zones against the Lewisian gneiss and Torridon Sandstone, while on the north the area is defined by a north-west and south-east dislocation. Thus a double system of normal faults—one set trending north-east, the other north-west—forms a characteristic feature in the structure of the Durness basin.

Arenaceous Series.—On the west side of the Kyle of Durness, both at Dail and south-west of Keoldale Pier, the double unconformability of the Basal Quartzites on the Gneiss and Torridon Sandstone is clearly displayed. For example, on Meall Sgribhinn, about six miles north-west of Durness village, where there is an important outlier of the lower Quartzite with the basal bands of the Pipe-rock, the Torridon Sandstones dip at

* By B. N. Peach and J. Horne. The district described in this chapter is comprised in Sheets 107, 108, 113, and 114 Geological Survey Map of Scotland, on the scale of 1 inch to a mile ($\frac{1}{63360}$).

gentle angles to the north-west and the overlying Cambrian beds to the E.S.E. Eastwards, near the mouth of the Kyle, at Dail, the red sandstones are overlapped by the quartzites till the latter rest directly on the ancient floor of gneiss. Confirmatory evidence of the transgression of the quartzites is obtained on the hill-slopes between Beinn a' Bhacaidh and Beinn an Amair, south-west of Keoldale Pier (Sheet 114), where a sequence can be traced from the basal breccia of the arenaceous series to Sub-zone 3 of the Pipe-rock, which is visible on the west shore of the Kyle. The higher bands of the latter sub-division occur in the southern part of the basin at Sithean Mòr (four and a half miles south-west of Durness), but they are there much obscured by peat and drift.

In the north-east corner of the area, between Smoo House and Sangobeag, both sub-divisions of the quartzite reappear, bounded by faults on either side.

The Middle Series.—The Fucoid-beds and *Salterella*-grit are not well exposed in the Durness area, owing partly to the covering of superficial deposits and partly to the interruption of the sections by the waters of the Kyle. Between Sithean Mor and Drochaidh Mhor, at the mouth of the River Dionard, isolated outcrops of these zones fix their position relatively to the quartzites and overlying limestones. Further north, about half a mile east of Keoldale House, the same zones are again met with in their proper stratigraphical position, but they are abruptly truncated by faults, and the exposures are incomplete.

Calcareous Series.—The dark leaden-coloured dolomites that overlie in normal order the Salterella-grit are well displayed at Rudha' a' Ghrudaidh—a promontory at the head of the Kyle of Durness—from which the lowest group of this series has been named, where they dip to the E.S.E. at 12°. But even here the sequence is not so perfect as that on the east shore of Loch Eireboll, to which attention will be directed in this Chapter. Proceeding from this promontory in a south-east direction to the great fault that bounds the Cambrian basin along its eastern margin, the observer crosses in order the overlying divisions of the Calcareous Series to the Croisaphuill beds (Group vi.), which are the highest that come in contact with that dislocation.

By far the best sections for studying the sequence, lithological characters, and palæontological sub-zones of this series occur in the north part of the basin, by the shore of Balnakiel Bay, and on the low ground southwards to Loch Borralaidh and east to the village of Durness, where a complete succession of the several members is exposed from the Eilean Dubh beds (Group ii.) to the fine-grained dolomites and limestones at the top (Group vii.). The general dip of the strata is here towards E.S.E., at angles varying from 15° to 30°, and their outcrops are shifted to some extent by normal faults. Indications of cleavage may be observed at certain localities—as, for instance, on the shore near Balnakiel Bay and north-west of Durness village. At the former place the dip of the bedding is 10°, that of the cleavage

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Arenaceous Series.—On the west side of the Kyle of Durness, both at Dail and south-west of Keoldale Pier, the double unconformability of the Basal Quartzites on the Gneiss and Torridon Sandstone is clearly displayed. For example, on Meall Sgribhinn, about six miles north-west of Durness village, where there is an important outlier of the lower Quartzite with the basal bands of the Pipe-rock, the Torridon Sandstones dip at

* By B. N. Peach and J. Horne. The district described in this chapter is comprised in Sheets 107, 108, 113, and 114 Geological Survey Map of Scotland, on the scale of 1 inch to a mile ($\frac{1}{63360}$).

gentle angles to the north-west and the overlying Cambrian beds to the E.S.E. Eastwards, near the mouth of the Kyle, at Dail, the red sandstones are overlapped by the quartzites till the latter rest directly on the ancient floor of gneiss. Confirmatory evidence of the transgression of the quartzites is obtained on the hill-slopes between Beinn a' Bhacaidh and Beinn an Amair, south-west of Keoldale Pier (Sheet 114), where a sequence can be traced from the basal breccia of the arenaceous series to Sub-zone 3 of the Pipe-rock, which is visible on the west shore of the Kyle. The higher bands of the latter sub-division occur in the southern part of the basin at Sithean Mòr (four and a half miles south-west of Durness), but they are there much obscured by peat and drift.

In the north-east corner of the area, between Smoo House and Sangobeag, both sub-divisions of the quartzite reappear, bounded by faults on either side.

The Middle Series.—The Fucoid-beds and *Salterella*-grit are not well exposed in the Durness area, owing partly to the covering of superficial deposits and partly to the interruption of the sections by the waters of the Kyle. Between Sithean Mor and Drochaidh Mhor, at the mouth of the River Dionard, isolated outcrops of these zones fix their position relatively to the quartzites and overlying limestones. Further north, about half a mile east of Keoldale House, the same zones are again met with in their proper stratigraphical position, but they are abruptly truncated by faults, and the exposures are incomplete.

Calcareous Series.—The dark leaden-coloured dolomites that overlie in normal order the Salterella-grit are well displayed at Rudha' a' Ghrudaidh—a promontory at the head of the Kyle of Durness—from which the lowest group of this series has been named, where they dip to the E.S.E. at 12°. But even here the sequence is not so perfect as that on the east shore of Loch Eireboll, to which attention will be directed in this Chapter. Proceeding from this promontory in a south-east direction to the great fault that bounds the Cambrian basin along its eastern margin, the observer crosses in order the overlying divisions of the Calcareous Series to the Croisaphuill beds (Group vi.), which are the highest that come in contact with that dislocation.

By far the best sections for studying the sequence, lithological characters, and palæontological sub-zones of this series occur in the north part of the basin, by the shore of Balnakiel Bay, and on the low ground southwards to Loch Borralaidh and east to the village of Durness, where a complete succession of the several members is exposed from the Eilean Dubh beds (Group ii.) to the fine-grained dolomites and limestones at the top (Group vii.). The general dip of the strata is here towards E.S.E., at angles varying from 15° to 30°, and their outcrops are shifted to some extent by normal faults. Indications of cleavage may be observed at certain localities—as, for instance, on the shore near Balnakiel Bay and north-west of Durness village. At the former place the dip of the bedding is 10°, that of the cleavage

45°; while the strike of the strata is N. 35° E., and that of the cleavage planes north and south.

Of special interest in this part of the Durness basin is the development of the two highly fossiliferous sub-divisions (Groups v. and vi.), which, in the field, are readily distinguishable by their lithological characters. The Balnakiel beds (Group v.), consisting of alternations of dark and light grey dolomite with some bands of limestone, are visible on the shore for a distance of 400 yards west of Balnakiel Farmhouse, and stretch south by the west side of Loch Croisaphuill, where their outcrops are shifted by a normal fault; but they are continued in the island in Loch Borralaidh and southwards to the Kyle west of Keoldale. Both on the shore and in various inland exposures the bands are charged with *Maclurea*, *Murchisonia*, *Ophileta*, *Pleurotomaria*, and other fossils. The members of the overlying Croisaphuill group are conspicuously developed on the ridges east of Loch Croisaphuill and of Loch Borralaidh, where the bands of massive dark-grey dolomites and limestones consist largely of worm-casts that project on the surface. The organic remains most commonly met with in these beds are those of *Maclurea*, especially opercula; *Piloceras*, and *Trocholites*.

Reference ought to be made to the fossiliferous localities in the southern part of the basin where these two groups (v. and vi.) are exposed, about four miles S.S.W. of Durness village. A suite of organic remains similar to those found between Loch Borralaidh and Balnakiel has been collected near an old Pictish tower by Bealach Mor, not far from the great fault that defines the eastern limit of the basin. Though isolated by faulting and denudation, the exposures of these two groups in different parts of the Durness area can be correlated by palæontological evidence.

The members of the highest sub-division (Group vii.), consisting of light-grey dolomites and limestones, with an occasional dark band charged with *Murchisonia*, are overlain in Sangomore Bay, near the village of Durness, by shattery quartzite, striped fissile schist, contorted schists, and gneiss. Though unquestionably resting on the limestone and sharing in the normal faulting of the district, these crystalline strata do not prove a conformable upward succession, as formerly supposed. The key to the reading of this and the corresponding section at Fair-aird Head is to be found in the Eireboll district, and will be described in detail in Part IV., Chapter XXXIII.

East of the great fault in Sango Bay that truncates the Durness basin, the representatives of the Sailmhor and Sangomore groups are again brought to the surface, where their characters may be studied in clear coast sections. The well-known Smoo Cave described by Professor Heddle* has been eroded out of the granular dolomites and white limestones of the Sangomore group.

* *Mineralog. Mag.*, vol. iv., pp. 171, 248-251.

As already stated, the dolomites and limestones of the Durness area are characterised by cherts, which are specially developed on certain horizons. The large spheroidal masses near the base of the Sailmhor group are well displayed on the shore a quarter of a mile east of Eilean Dubh in Balnakiel Bay; the bands at the base of the Sangomore sub-division may be studied in the cliffs of the inlet leading to Smoo Cave*, and the lines of small chert nodules in the Croisaphuill group are exposed on the rocky knolls east of the loch of that name and east of Loch Borralaidh.

Far to the west of the Durness basin, on An Garbh-eilean, Eilean nan Cas-leac, and at Port Odhar, representatives of the Balnakiel and Croisaphuill groups, with their characteristic fossils, are met with, bounded on the south by a powerful north-west and south-east fault. Their probable relation to the crystalline schists of Fair-aird Head will be described in Part IV. Again, on Eilean Hoan, east of Durness village, and about a mile E.N.E. of Smoo, dolomites and limestones, much disturbed by faults, have been correlated with Groups ii., iii., and v. of the Durness sequence.

2. *Loch Eireboll to Loch More.*

The Cambrian strata of the Durness basin are separated from those at Loch Eireboll by a prominent ridge of Lewisian gneiss, which, beginning on the shore at Ceannabeinne, extends south by Beinn Spionnaidh, Foinne-Bheinn, and Beinn Arcuil to Loch More.

The Quartzites.—The crest and eastern slope of this ridge are covered by the members of the arenaceous series, which, to the west of the post-Cambrian displacements, have a gentle dip to the E.S.E. Throughout the whole of this tract the basal quartzites rest directly on the Lewisian gneiss, and the peculiar decomposition of the felspar in the rocks of the underlying platform may be studied close to the unconformable junction on the slopes of Beinn Spionnaidh, of Crann Stacach, and by the road between Rispond and Port nan Con.

The best development of the pebbly grit or fine conglomerate at the base of the quartzites in this northern region occurs on a col at a height of about 900 feet, and about one mile south of Meall Meadhonach, west of Loch Eireboll, where bands of coarse pebbly grit and fine conglomerate alternate with gritty quartzite for about ten feet. In the coarser bands the pebbles vary from a quarter of an inch to an inch across, and consist of pink and white quartz, felspar, jasper, altered quartzite, and felsite, among which one small fragment of grey gneiss has been observed. Such a development is, however, quite exceptional, for, as a rule, the conglomeratic or pebbly bed is only about a foot thick.

* Professor Heddle gives an analysis of the bands of chert in the Sangomore Group from this locality.—*Mineralog. Mag.*, vol. iv., p. 250.

Outliers of quartzite appear to the west of the main belt, of which, perhaps, the most interesting is to be seen about half a mile W.S.W. of Meall Meadhonach, where a patch of the lower zone with some basal bands of pipe-rock is truncated by a north-east fault—the higher of the two parallel dislocations that throw down the Durness basin. Small detached masses of the basal quartzites, isolated by denudation, appear on the gneiss platform, as, for instance, on Ceann Garbh—one of the peaks of Foinne-Bheinn—at a height of 2952 feet. Again, within the belt of quartzite west of Loch Eireboll, outliers of the lower zones of the pipe-rock rest on the basal quartzites, showing the unequal erosion of the members of the arenaceous series. All the sub-zones of this division have been identified, though not mapped, in the Eireboll region, partly in the undisturbed and partly in the thrust masses. The total thickness of this series in this northern area is between 500 and 600 feet.

Between the head of Loch Eireboll and Loch More a striking feature presented by the quartzites on the eastern slope of the lofty ridge of gneiss is the reduplication of the various zones by the post-Cambrian movements, to which attention will be directed in Part IV. Among these displaced materials, serpulites (*Salterella*) were found in a massive band of quartzite at the top of Sub-zone 3 of the pipe-rock (the sub-division with the trumpet-shaped worm burrows) at Lochan na Faoilege, on the east slope of Beinn Arcuil (Sheet 108, one-inch).

On the east side of Loch Eireboll the quartzites appear among the thrust masses, and have been traced in more or less continuous belts from the northern headland of Mol Mhor, south-west by Ben Heilem and Camas an Duin, to the head of that sea-loch. At various localities in this tract the basal breccia has been found in contact with the upturned floor of Lewisian gneiss, and the sub-zones of the pipe-rock are characteristically developed.

Fucoid Beds, Salterella Grit, and Limestone.

One of the best sections showing the lithological characters and palæontological sub-zones from the base of the Fucoid-beds to the top of the dolomites and limestones of the Ghrudaidh group occurs on the promontory of An t-Sron, on the east side of Loch Eireboll, about a mile south of Heilem. The structural relations of the strata will be described in the sequel (Part IV., Chapter XXXIII.), but the order of succession and thickness of the bands are given in the following vertical section :—

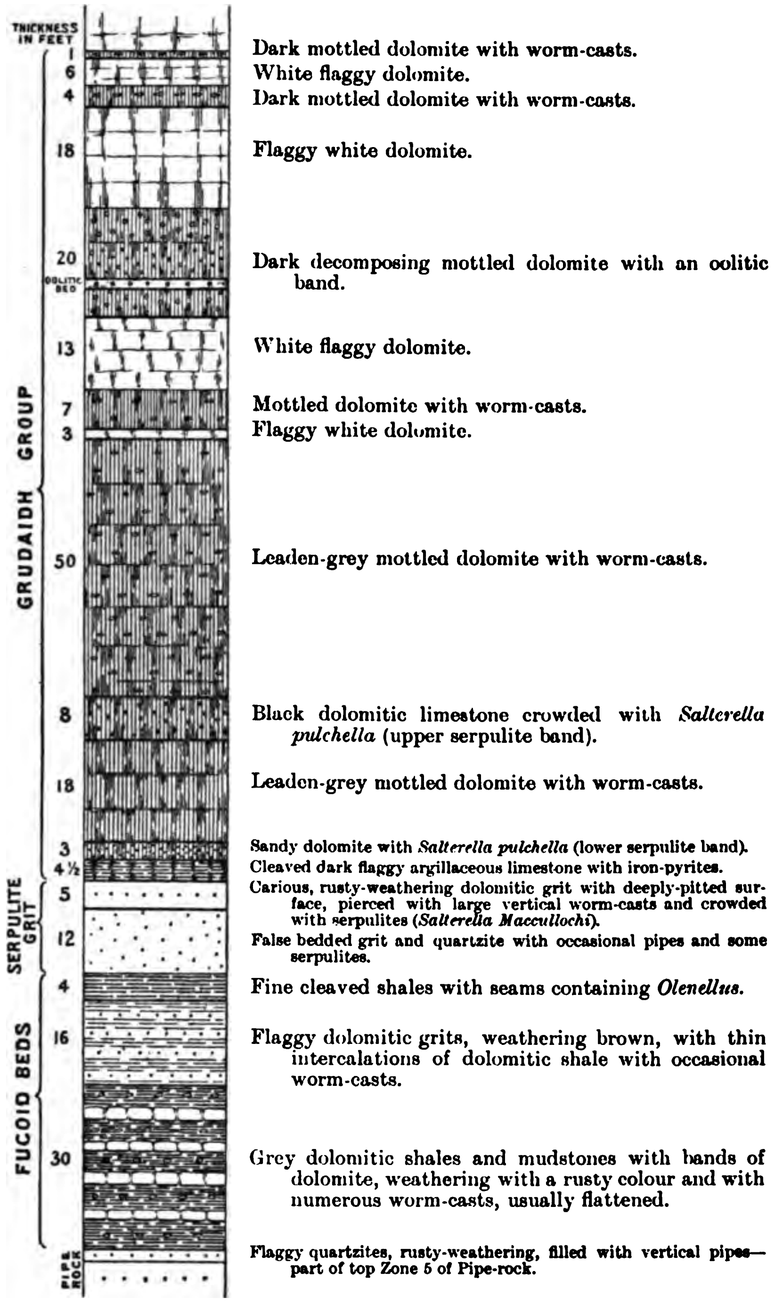

FIG. 17.—Vertical Section of Fucoid Beds, Serpulite Grit, and Ghrudaidh Dolomite and Limestone—An t-Sron, east side of Loch Eireboll.

A special interest attaches to this section from the occurrence of fragments of *Olenellus* in the sub-zone of fine cleaved shales at the top of the Fucoid-beds, so clearly exposed on the promontory of An t-Sron. The band from which these important fossils were obtained is only a few inches thick, and consists of soft cream-coloured shale—blue in fresh fracture—closely resembling the layer in the typical section on Meall a' Ghubhais, Kinlochewe, Ross-shire (see Chapter XXVII.), which is there crowded with fragments of that trilobite, and has therefore been termed the *Olenellus* layer. If the correlation of these two sub-zones be correct, then there must be a lateral modification of the higher portion of the Fucoid-beds between Kinlochewe and Loch Eireboll, for at the latter locality the thick mass of "piped" shales with vertical worm-casts which overlie the *Olenellus* layer on Meall a' Ghubhais is absent (p. 414).

Numerous exposures of the Fucoid-beds, usually in association with the *Salterella* grit and a portion of the basal limestone, occur in the displaced masses on the east side of Loch Eireboll and in the mountainous tract between the head of that sea-loch and Loch More. But the bands occupying the horizon of the *Olenellus* layer are so affected by movement that there is little prospect of obtaining organic remains from these outcrops. South of An t-Sron, in the direction of Eireboll House, towards the head of the sea-loch, a considerable area is occupied by the Eilean Dubh dolomite and limestone—the highest sub-division in this region.

CHAPTER XXV.

CAMBRIAN STRATA FROM LOCH MORE TO STRATH KANAIRD.*

1. *Loch More and Glencoul District.*†

Between Loch More and Loch Glencoul the Quartzite forms in most places a rather prominent crag with a general N.N.E. strike, its lower beds dipping to south-east or E.S.E. at angles between 8° and 14°. The base is generally concealed under drift, but it is probably not much affected by thrusts. The false-bedded quartzite forms most of the crag, and, excepting for about a mile and a quarter on the north side of Loch an Leathaid Bhuain, its outcrop is rarely more than 150 yards in breadth. The piped quartzite makes a much broader outcrop, partly because of the more gentle slope of the ground which it occupies, and partly because of the folds and thrusts which affect it. On the north side of Loch an Leathaid Bhuain the outcrop of the piped quartzite is unusually wide, often more than three-quarters of a mile. In the eastern half of this tract the dip is very variable; there are some sharp folds with axes striking N.N.E., and probably several thrusts also.

On the north-west side of the Loch More crag a small outlier of quartzite rests unconformably on the Lewisian gneiss of Ben Stack. The outlier has its north-western end 70 or 80 yards south-east from the top of the hill, and extends for 300 yards in a south-easterly direction. It is not more than 116 yards broad in its widest part, and does not contain more than a thickness of about 50 feet of beds. The general dip is here much the same as in the Loch More crag.

On the east side of the Loch More-Loch Glencoul band of quartzite many portions of the same strata have been separated from it by thrusts, usually with considerable intervening breadths of gneiss. In these detached exposures, wherever the unconformable base of the quartzite can be seen, it rests on rocks belonging to the Lewisian gneiss series, as in the unthrust area to the north-west.

The thrust quartzite which runs E.S.E. from near the middle of the south side of Loch na Creige Duibhe, can be traced for

* The district described in this chapter is represented in Sheets 101, 102, 107, 108 of the Geological Survey Map of Scotland, on the scale of 1 inch to a mile ($\frac{1}{63360}$).

† By C. T. Clough.

more than a mile, and in this space it does not show much disturbance or alteration. South-west of Beinn Lice another exposure of thrust quartzite, more than a mile in length and breadth, rises up in a dome from beneath the fucoid-shales, and reveals in its centre a small inlier of gneiss.

Some of the masses of quartzite which have been brought forward by the higher thrusts have been considerably reduced in thickness by the movement. Thus the dragging out and thinning to which the piped quartzite has been subjected is well shown by the bending and deformation of its pipes. In the undisturbed ground the pipes are always perpendicular to the bedding planes, but in the thrust area they are often diagonal. The deformation has evidently been greatest in the thin-bedded bands and those which contain a certain admixture of shaly material.

Basal Conglomerate.—At each end of the quartzite outlier on Ben Stack a basal conglomerate, at least 18 inches thick, may be observed, in which the larger pebbles, two or three inches long, consist chiefly of red and white quartz, like vein-quartz, and a jasper-like rock. The jasper-like pebbles resemble some of those in the Torridon rocks. Above the conglomerate comes a soft, fine-grained, rather shaly band, which, in the blocks along the outcrop, generally adheres closely to it. The gneiss 180 yards north-west from the outlier contains a pegmatite with a little agalmatolite—a common indication of the proximity of a pre-Cambrian surface. Between Loch More and Loch an Leathaid Bhuain the base of the quartzite is always hidden by drift, but about a mile slightly north of east of Loch Poll an Achaidh Bhuidhe many loose blocks of conglomerate, resembling that on Ben Stack, probably indicate the approximate position of the base of the quartzite.

The basal conglomerate is seen on the north side of Beinn a' Bhùtha (north-east of Loch Glendhu), little more than half a mile north of the hill top; also at the north end of the gneiss inlier a third of a mile west of Lochain nan Ealachan (south of Loch More), where it shows a reversed dip, with pebbles of quartz two or three inches long; about 1100 yards E.S.E. of the foot of Loch Strath nan Asinnteach, where it is well exposed, and is repeated several times by small thrusts. In the gneiss below the quartzite half a mile north-east of the top of Beinn Aird da Loch (between Lochs Glendhu and Glencoul), a pegmatite with the felspar converted into agalmatolite, affords an indication of a pre-Cambrian floor, from which the Cambrian strata have been removed. In the Glencoul River, half a mile slightly west of north of Loch nam Caorach, the basal conglomerate is in some places only an inch thick. A thin basal conglomerate is also seen nearly half a mile south, about 700 yards S.S.E., and three-quarters of a mile S.S.E. of the south end of this loch.

False-bedded Quartzite.—The false-bedded quartzite rather more than a quarter of a mile west of Glendhu House shows some shaly partings, probably near the base. This sub-division likewise appears on the scars on the north side of Loch Glencoul, where the uppermost bed is much redder than those below it, is more conspicuously false-bedded, and occasionally presents the tops of small pipes on its bedding planes. The same sub-division of the quartzite appears in the thrust areas near Lochain Feith an Leathaid, where its thickness is estimated to be about 150 feet.

Piped Quartzite.—The piped quartzite between Loch More and Loch Glencoul having been mapped before the zones in the arenaceous series were definitely established, we cannot say whether the zones in this area always agree exactly with those determined elsewhere. In the scars on the north side of Loch Glencoul, about 50 feet above the base of the piped quartzite, are various bands of rather coarse-grained purple piped rock in which the pipes are generally less deeply coloured than the rock at their sides. In most places the purple bands are parallel to the bedding surfaces, but this is not always so, and it is probable that the colour of some parts is due to staining. Bands of a purple tint occur in some places as far down as the base of the piped rock, and even into the top beds of the false-bedded quartzite. The quartzite scar owes its reddish appearance in the landscape partly, perhaps, to these bands, but chiefly to hæmatite staining on the joint faces and in crush breccias. The base of the trumpet zone is about 80 feet above the bottom of the piped rock. Above this zone comes, first, a rather massive bed which shows no distinct pipes, and which weathers with a dirty yellow colour; then an alternation of thin red and white piped bands—the sub-zone 4—followed by massive white and pale-pink piped rock, up to the top band, which consists of thin red and purple beds of rather coarse grain, and is between eight and twelve feet thick. The highest band is crowded with pipes, and contains a few thin shaly beds rather like parts of the fucoid shale.

Near the north-east corner of Loch na Creige Duibhe (two miles north of Glendhu) the piped quartzite includes some reddish purple seams, which are sometimes curved and twisted, though the general bedding planes are even. The colour, which may be due to staining, only occurs on certain horizons.

A little south of Lochain Feith an Leathaid (east of Glencoul) most of the pipes near the base of the pipe-rock are, as usual, of much smaller diameter than those higher up, but within the small pipe zone, about 12 feet from the base, some layers enclose broader pipes. For 80 feet above the bottom the piped quartzite is generally of a massive character, and either white or pale-pink in colour. This portion is succeeded by a few thin beds, not more than two feet in thickness altogether, of a red or purple colour, but with paler or almost white pipes, and then comes the trumpet-zone.

Three-quarters of a mile south of Lochan nan Caorach (south-east of Loch Glencoul) a band of thin-bedded purple and blue pipe-rock lies 40 or 50 feet above the base of the pipe-rock. It comes below the trumpet-pipe zone, from which it is separated by a white compact massive piped rock. The section at the top of the quartzite is here as follows, beginning at the top:—

> Horizon with some shaly beds, but with distinct pipes, 6-10 feet.
> Massive white or pale-pink piped rock, with some thin blue and purple bands, 30-40 feet.
> Thin-bedded, reddish-purple rock with paler pipes (sub-zone 4.)
> The Trumpet zone.

Fucoid Shales.—Between Loch More and Loch na Creige Duibhe, only one exposure of fucoid shale has not been moved forward by thrusts. It lies about half a mile W.S.W. of Lochmore Lodge, and makes a little scar overlooking the quartzite and continuing distinct for a length of 300 yards or more. It is 50 yards broad, but it may not include the top beds, for a thrust comes in on its southern side before any serpulite grit is seen. Between Loch na Creige Duibhe and Glencoul a continuous outcrop of unthrust fucoid shale may possibly overlie the quartzite, but in most places the ground where the shale should be is covered with drift. The same zone is to be seen about 1500 yards east of the foot of Loch an Leathaid Bhuain, and in the burn 220 yards north of Glendhu House. At both these places the full thickness of the shale is probably represented, with the serpulite grit lying naturally over it. In the coast-section nearly a third of a mile north-west of Glencoul House, some fucoid shale lies above the quartzite, and below the lowest of the great thrusts—the "sole," which carries the piled-up stripes of fucoid shales, serpulite grit, and limestone.

This sub-division of the Cambrian series probably extends over considerable areas in many parts of the thrust region, but most of this ground is largely obscured, owing presumably to the softness of the shales and their tendency to form low ground. The best sections are to be seen on the coast and in the islands near Glencoul, but they are much confused with small thrusts, and the shales are crossed by a conspicuous cleavage. Perhaps the best inland exposures are those which occur about 700 yards north-east of the head of Loch na Creige Duibhe, rather more than a mile south-east of the head of Loch Glendhu, and south-east of Loch nan Caorach. In the last locality the area which is probably occupied by the shales has a length of more than two-thirds of a mile, and in one place a breadth of 300 yards. In several places among the thrust shales about half a mile south-east of Lochmore Lodge, and in the islands near Glencoul, thin bands of compact cream-coloured limestone make their appearance, weathering with a rusty surface, and differing in character from any part of the Ghrudaidh limestone. They are not, probably, to be regarded as wedges of this limestone pushed in along thrusts.

Serpulite Grit.—Between Loch More and Glencoul only two exposures of this sub-division appear to occur in an unthrust condition, the one about three-quarters of a mile slightly south of east of the mouth of Loch na Leathaid Bhuain, the other in a little burn 270 yards north of Glendhu House.

Good exposures of the thrust grit may be seen on the south-east side of Lochmore Lodge, on the north side of Loch na Creige Duibhe, on the south and south-east sides of Beinn a' Ghrianain, on the south-east side of Loch na Caorach, and close to Glencoul House. Remains of the serpulites have not been met with in so many places as might have been expected. They are very distinct in the grit 1100 yards E.N.E. of the top of Beinn a' Bhutha, and three-quarters of a mile slightly north of west of the top of Beinn Lice, south side of Loch More.

Calcareous Series.—Between Loch More and Glencoul no portion of the Durness Limestone appears in an unthrust condition, and the different outcrops of this series are either much disturbed or else to a large extent hidden under drift. Probably by far the largest outcrop occurs in the valley* at the head of Loch na Creige Duibhe. For a mile and a quarter above the loch the limestone may average a third of a mile in width. It continues in a narrower band under Beinn Lice, and further south it appears to expand and to attain again perhaps in one place a width of a third of a mile. In the valley referred to, many swallow holes, generally opening to the surface through drift, indicate the position of the calcareous series below. The bare limestone is almost confined to the loch side or to the banks of the burn a little above the loch.

In the valley above Loch na Creige Duibhe several different zones of the Ghrudaidh limestone may be discerned, including some oolitic bands, a dark-grey brecciated band, and a black massive limestone with worm ejecta; but the exposures are not clear enough to show the thicknesses or relations of the different zones. Rather more than a third of a mile S.S.E. of the mouth of the burn at the head of the loch, and also on the hill 1100 yards E.N.E. of the loch, the oolitic structure is partially preserved in chert.

In this area the Eilean Dubh limestone is only known on the hill E.N.E. of Loch na Creige Duibhe and in the outcrop which extends south-east from the head of this loch. In the valley above the loch, and also near Beinn Lice, the boundaries between the Ghrudaidh and the Eilean Dubh limestone are much obscured by drift, but we suppose that the latter limestone probably extends all the way from the loch to rather more than a mile south of the top of Beinn Lice. There are also some small detached pieces of it near the loch side. About 300 yards south of the mouth of the burn at the head of Loch na Creige Duibhe, the limestone contains some thin white chert bands.

2. *Assynt.*†

The two members of the arenaceous series are well displayed on the eastern slopes of Quinaig. The summit of Spidean

* Called Strath nan Caran in the six-inch maps.

† The first three paragraphs of this section are by L. W. Hinxman; the rest are by B. N. Peach and J. Horne.

Coinich is capped with nearly 300 feet of quartzite, including the whole of the basal zone and the two lower sub-zones of the pipe-rock. A small outlier of the basal beds likewise caps the highest peak, south of Sail Gharbh. From Spidean Coinich long glaciated dip-slopes of pipe-rock, dipping east by south at 12°-15°, descend to the Allt Sgiathaig.

The unconformable junction with the underlying Torridonian series is well seen on the summit, along the flank of Creag Mhor, and on the west side of Druim na h'Uamha Moire. The base of the quartzite is usually a thin bed of conglomerate, containing pebbles of quartz and felspar half an inch to an inch and a half in length. The conglomerate is succeeded by coarse pinkish false-bedded grit, with two or three thin bands of green micaceous sandy shale. The outcrop of the basal quartzite crosses the Kylesku road one-third of a mile north-west of Loch na Gainmhich, and, creeping gradually over the Torridonian strata under Cnoc Coir' a Bhaic, overlaps on to the gneiss half a mile from the shore of Loch Glencoul. Sub-zones (1-4) of the pipe-rock are exposed in the deep gorge cut by the stream flowing out of Loch na Gainmhich; and a good section of the flaggy and often ripple-marked beds of sub-zone (3), with very large pipes, is seen along the Allt Sgiathaig, near Lochan Feoir.

The Cambrian rocks are again seen resting unconformably on the Lewisian gneiss further south between Loch nam Meallan Liatha and the foot of Canisp. A small inlier of gneiss has been exposed by denudation in the lower part of a small burn which falls into the Loanan nearly opposite Stronechrubie. The quartzite covers the summit of Canisp, and extends eastwards to the River Loanan and Loch Awe, and southwards to Cama Loch. Its strata are inclined to E.S.E., at angles varying from 16°-18° on the top of Canisp to 6°-12° on the lower slopes. The general easterly inclination of these slopes nearly coincides in amount with that of the dip of the beds, so that as we descend the hill-sides toward the Loanan we pass, as the form of the ground varies, alternately from pipe-rock to basal quartzite. The irregular arrangement of the outcrops is further complicated by the occurrence of numerous normal faults, and by the sills of Canisp porphyry, which are intruded at different horizons in the quartzite along the slopes of Leathad Lionach.

In the undisturbed area between Loch Glencoul and Loch Assynt, the fucoid-beds follow the pipe-rock in natural sequence, but over the greater part of this distance only the lower portion of the zone lies to the west of the first line of displacement. On the north shore of Loch Assynt, however, and in the ground immediately to the north thereof, the most westerly thrust appears in the lowest group of dolomites (Ghrudaidh group), and at these localities there are excellent sections of all the sub-divisions of the Middle Series, including the bands that yield the *Olenellus* fauna. These appear to the east and north-east of the mouth of Skiag Burn (Allt Sgiathaig on Sheet 107), about two miles N.N.W. of Inchnadamff Hotel, where the fucoid-beds and serpulite-grit are laid bare on the shore of the loch, and form prominent escarpments on the adjoining slope. The thickness of the former zone is there 42 feet 8 inches, and that of the latter 29 feet 8 inches.

On the slope about 200 yards N.N.E. of Skiag Bridge, A. Macconochie found a thin seam crowded with fragments of *Olenellus*, the position of which is shown in the subjoined section.

	Ft.	In.
8. Serpulite grit with abundant examples of *Salterella*	-	—
7. Blue shale with small pipes	2	9
6. Soft cream-coloured shale with numerous fragments of *Olenellus*, particularly of *O. Lapworthi*	0	3
5. Well-bedded sandy dolomitic bands with flattened worm-casts	4	0
4. Finely-bedded blue shale with *Hyolithes*	1	6
3. Irregularly-bedded dolomitic bands	3	0
2. Blue shale	5	0
1. Massive Fucoid beds at the base.		

Following this outcrop southward to the margin of the lake, the observer there finds the soft shale, charged with fragments of *Olenellus*, about three feet from the base of the serpulite-grit. It is interesting to note that the position of this important sub-zone at Loch Assynt closely corresponds with its horizon at An t-Sron, on the east shore of Loch Eireboll, and differs to some extent from that in the typical section south of Kinlochewe in Ross-shire (pp. 394 and 414).

The overlying serpulite-grit, which forms a small area on both sides of the road east of Skiag Bridge, is there divisible into two portions—an upper bed with carious layers, crowded with *Salterella Maccullochi*, and a lower one in which that organism occurs sporadically, sometimes as dark solid bodies, and again as hollow casts. The worm burrows are also typically represented, in some instances in the solid form, and in others they are dissolved out, thus giving the rock the appearance of a log of wood bored with teredos. Next in order come the basal beds of the lowest group of dolomites and limestones (Ghrudaidh), comprising the calcareous shales and both bands of dolomite containing *Salterella*, the upper one being 30 feet above the serpulite-grit. A few yards to the east the section is interrupted by the first reversed fault.

For some distance south of Loch Assynt the Fucoid-beds are not visible in the undisturbed area, being concealed by drift and alluvium, but beyond Stronechrubie, between Allt nan Uamh and Elphin, they appear at intervals overlain by the serpulite-grit and occasionally by a patch of the basal limestone, all in natural sequence.

In the sequel (Part IV.), detailed descriptions are given of the extraordinary reduplication of the members of this system in the area affected by the post-Cambrian movements. Within that area, the double unconformability of the quartzite on the Torridon Sandstone and Lewisian gneiss can still be detected on

Ben More, on Sgonnan Mor north of Loch Ailsh, and again on Beinn an Fhuarain, about three miles south of Inchnadamff Hotel. Both divisions of the arenaceous series are largely represented on the lofty ridge that extends from Glas Bheinn by Beinn Uidhe to Ben More, and southwards by Braebag to the sources of the Ledbeg River at Luban Croma. On the east side of that watershed they are traceable from Gorm Loch Mor southwards to near Kinlochailsh, where they display in a marked degree the effects of post-Cambrian movements. South of the mountainous region of Assynt, outliers of quartzite, sometimes with a core of thrust Lewisian gneiss, are found at various localities—as, for instance, one mile south of Elphin, between Cama Loch and Loch Urigill, on the moor one and a half miles south of the latter lake, and on Cnoc Glas Choille and Cnoc a' Chaoruinn, about five and six miles respectively south-east of Elphin.

In Assynt, where the five sub-zones of the pipe-rock were first detected, measurements of their thicknesses were taken, and are given below in descending order:—

Sub-zone 5.	Massive purple grit with vertical pipes -	36 feet.
,, 4.	Flaggy quartzites with pink and white seams, the pipes usually of a different colour from the matrix; the lower beds varying from 2 to 6 inches in thickness -	48 ,,
,, 3.	Massive fine-grained white quartzite with rusty surface, probably on the horizon of the *Salterella* band on Beinn Arcuil -	15 ,,
	Flaggy quartzites, sometimes false-bedded, with certain bands containing large pipes 3 or 4 inches across, and passing downwards into white pipe-rock - - -	75 ,,
,, 2.	Massive quartzite in bands from 1 to 3 feet thick, with small pipes about $\frac{1}{2}$-inch in diameter - - - - - -	74 ,,
,, 1.	Massive white saccharoidal quartzite beds, averaging from 3 to 4 feet in thickness, with small pipes about $\frac{1}{8}$-inch in diameter	27 ,,
		275 feet.

It is worthy of note that the lithological character of the strata forming the highest sub-zone of the pipe-rock in Assynt differs considerably from that in the Eireboll region. In Assynt the prominent feature is a coarse friable quartzose grit with vertical pipes, while at Eireboll the rock is hard compact quartzite, becoming flaggy towards the top, with bands of rusty shale.

Throughout the thrust area in Assynt the members of the Middle Series have a wide distribution, to which only a brief allusion can here be made. They cover broad areas in the hollow along Allt Sgiathaig, south-east of Quinag, and on the crest of Beinn an Fhurain (two and a half miles east of Inchnadamff).

They extend up the valley of the Traligill, and form narrow strips along the crest and western slopes of Breabag. Far to the east they appear at Loch Ailsh, and on the western slopes of Cnoc a' Chaoruinn, and to the south on the peaty moorland north-west and south-east of Loch Urigill.

In like manner, the members of the Calcareous Series have a large development among the displaced masses in Assynt. From the base of the western slope of Glas Bheinn they stretch southwards by Achumore to the Traligill and Allt nan Uamh (two and a half miles south of Inchnadamff), near which the belt is about two miles broad. The highest beds, forming part of the Sailmhor division (Group III.), are exposed on the plateau a mile and a half south-east of Inchnadamff Hotel. It is interesting to observe that all the sub-zones of the lowest group (Ghrudaidh) met with in Eireboll have been identified on the plateau between Achumore and Inchnadamff, where the total thickness of this subdivision is 115 feet. South of the mountainous region the dolomites and limestones stretch across the peaty moorland south-east of Elphin for a distance of four miles, where only the two lowest sub-divisions are represented.

A feature of special interest in the south-eastern part of Assynt is the contact metamorphism of the dolomites and limestones by the post-Cambrian intrusive rocks, to which attention will be directed in Chapter XXXI. Where these have been invaded by the great plutonic mass of Cnoc na Sroine and Loch Borrolan (six miles south of Inchnadamff), they have been altered into saccharoidal marbles, which, at several localities, were formerly quarried. In the tract between Loch Awe and the Ledbeg River above Loyne a gradual passage can be traced from the normal dolomites and limestones of the Ghrudaidh and Eilean Dubh groups into the crystalline marbles, in which the original characters are effaced. The stratigraphical horizon of the calcareous bands is proved by their position relative to the fucoid-beds and *Salterella*-grit. As shown in Sheet 101, repeated outcrops of the latter zones occur between Loch Awe and Loyne, and again about half a mile up stream from the shepherd's house, in association with the overlying dolomites and limestones.

As the area covered by the granite and syenite east and west of Loch Borrolan is large, the marble has a wide distribution. In addition to the exposures on the south bank of the Ledbeg River above Loyne, it appears in that stream between Loyne and Ledbeg, and on the hill slope about half a mile north-west of the latter cottage. On the southern margin of the igneous mass, it is found on the north shore of Loch Urigill and on the moor between that lake and Ledmore; on the east, it appears west of Cnoc a' Chaoruinn by the road leading to Loch Ailsh and on the moor northwards to Strathsheaskich (Sheet 102); while towards the north it is visible in some streamlets draining southwestwards towards Luban Croma. At the last of these places the marble is in contact with borolanite.

3. *Knockan to Strath Kanaird.**

The fucoid-beds and serpulite-grit are very well displayed along the line of the Ullapool road between Elphin and Strath Kanaird. The eastern slopes of Cul Mor are occupied by the basal quartzite, resting unconformably on the Torridonian Sandstone, and succeeded near the foot of the hill by the pipe-rock, both dipping south-east at angles varying from 12° to 20°. The fucoid-beds and serpulite-grit follow in natural sequence, and are seen in vertical section at the roadside immediately west of the village of Knockan, and at the foot of the Knockan cliff. The lower shales of the fucoid-beds are here typically developed, and are crowded with flattened worm-casts (the so-called "fucoids"). The soft shale band, which in other localities has yielded abundant remains of trilobites, was here found to be unproductive, but fragments of *Olenellus Lapworthi* were obtained by A. Macconochie in a thin calcareous band immediately overlying the shale.

At the southern end of Cnoc-an-t-Sasunnaich (two and a half miles south-west of Elphin), a north and south fault crosses Lochan Fasaidh and throws the Cambrian outcrops down below the road. From this point southwards the Cambrian strata are compressed into a belt not more than one-third of a mile in average width, and they rise in a series of low escarpments inclined to south-east at 16°-22° from the valley of the Runie River to the level of the road between Drumrunie Lodge and Achendrean. Crags of the dolomitic limestone of the fucoid-beds with bright ochreous weathering are conspicuous at several points along the roadside, and are known as the Clachan Ruaidh (Red Stones). At Achendrean the fucoid-beds and serpulite-grit descend to the River Kanaird, and are there shifted half a mile up the valley to Achnacairnen by the left-hand branch of the powerful Strath Kanaird fault.

* By L. W. Hinxman.

CHAPTER XXVI.

CAMBRIAN AREA FROM STRATH KANAIRD TO STRATH NA SHEALLAG.*

In Strath Kanaird the quartzite is repeated by a north-east fault. Its western portion rises to no great altitude, and soon ends to southward, while the eastern forms a narrow band extending to Loch Broom. Near Creag na h Iolaire it reaches a height of more than 900 feet, and in Creag na Feola of 824 feet. From the sea-level at Loch Broom it rises to 1400 feet near Loch Sagaidh, to fall again in the valley of Little Loch Broom, whence it rises gradually to over 1500 feet to the east of An Teallach, while in the three outliers on the spurs of that mountain it exceeds a height of 3000 feet. Along the greater part of its course the quartzite forms a series of crags facing the west, with dip slopes to the east. These white steep slopes, very noticeable to the south of Dundonnell, are beautifully polished by glacial action, and as the dip is from 15° to 20°, they are in some places impassable. Except near Ullapool, the thrust Cambrian strata lie generally at a lower elevation than those which have not been involved in the displacements. The higher Cambrian rocks (limestone and fucoid-beds) do not form conspicuous features in the district, and as a general rule occur at lower altitudes than the quartzite.

Although the Cambrian quartzite is, here as elsewhere, unconformable on the Torridon Sandstone, few sections in this district exhibit the fact in small compass. The base of the quartzite is usually marked by a conglomerate, sometimes eight or ten feet thick, which, while it has been in the main derived from the Torridon Sandstone, is quite different in character from that rock. But it must be confessed that there often seems to be no marked difference of dip in the two formations either as regards direction or amount. Probably, taken all together, the dip of the Torridon Sandstone is more variable and at lower angles than that of the overlying quartzite. It does not average more than 10°, while in the quartzite the inclination is almost everywhere from 15° to 20°. Further, the direction of dip in the Torridon series is generally towards south-east, while that of the quartzite is steadily about E.S.E. In certain places,

* By W. Gunn. The district described in this chapter is comprised in Sheets 92 and 101 of the Geological Survey Map of Scotland, on the scale of 1 inch to a mile ($\frac{1}{63360}$).

indeed, the unconformability is strikingly visible, as on the south side of Beinn Giubhais, north of the Ullapool River; under Cnoc na Croiche, to the north of Hill Cottage, Ullapool; and on the ground to the east of the Royal Hotel. Perhaps, however, the best section in this district to show the unconformability between the two formations is to be seen near the quarry to the south-east of the hotel, not far from the smithy, where the irregularly-bedded and nearly horizontal Torridon Sandstone is overlain by the quartzite, which presents its usual steady dip of 12°-15° to the E.S.E.

Quartzite.—Generally throughout this district the lower portion of the Cambrian series, from the base of the quartzite up to the serpulite grit, can be traced in complete or unbroken succession; but the Durness limestone is not continuous, and is more or less thrust almost everywhere. It principally occurs between Strathkanaird and the Ullapool River, and is conspicuous at the latter place. South of Loch Broom it is only found in one place, east of Dundonnell Lodge. The thrust quartzite which occurs north of the Ullapool valley is mostly pipe-rock, or the upper division. The basal quartzite in this area seems generally, from the mean of several estimates or measured sections, to be about 325 feet thick, and the pipe-rock from 250 to 300 feet. The basal breccia or conglomerate may be seen at Creag na h Iolaire, to the north of Ullapool. It is well exposed south of Loch Broom, near the small lochs west of Loch Lagaidh, and in the main burn east of Dundonnell Lodge. In the burn west of Camas a Chonnaidh, Loch Broom, where it reaches a thickness of 10 feet, it is mainly pink in colour from the large felspar fragments derived from the underlying Torridon Sandstone. The false-bedding of the basal quartzite is well exhibited by the roadside to the south-east of Ullapool, about 500 yards east of the Royal Hotel, where, while the true dip in white quartzite is 12° to 15° to E.S.E., the false-bedding dips S. 30° E. at 25°-30°. About 150 yards farther east the true bedding preserves the same inclination and direction, but the false-bedding dips S. 35° E. at 20°-25°. This basal quartzite is banded, pink and white, and is generally coarse—in fact, some parts of it may be called conglomerate. Coarse or gritty bands abound in it, and in the stream east of Dundonnell Lodge it includes a thin band of hard shale several inches thick. A similar or perhaps the same band was observed by the side of the fault due east from the middle spur of An Teallach.

The usual sub-divisions in the pipe-rock can be traced through this district, and sections of them abound in the scars and streams. Perhaps the best general section of the Cambrian rocks here to be found lies along the banks of the Ullapool River, to the north-east of Ullapool. The white glaciated quartzite is conspicuous in the scars to the east of Ullapool and along the shores of Loch Broom, south from that village. A fine exposure of the vertical pipes may be seen in a scar by the side of the fault which crosses the quartzite in a north-east direction on the south side of the valley of Little Loch Broom and south-west of Corryhallie. As a general rule, the most prominent inland quartzite-scars are formed by the false-bedded quartzite, together with a portion of the overlying pipe rock, but the whole thickness of the quartzite is never to be seen here in any single scar. Good sections are displayed on Creag na Feola, a mile and a half north of Ullapool, and at Creag na Fhithich, on the south side of Loch Broom, to the west of Camas a Chonnaidh.

The upper zones of the pipe-rock are well exposed in a low scar by the roadside opposite the Braes of Ullapool, the coarse red grit being particularly well seen, and the following section was measured to the east of a small stream called Allt Glac an't Seilich, which falls into the Ullapool River on the north side about a mile and a quarter above the bridge:—

	Ft.	In.
Fucoid Beds.		
Piped quartzite, thin and impure towards the top, -	20	0
Grit, red below and whitish-yellow above, - - -	2	6
Grit, coarse, red, piped, - - - - - - -	6	6
Gap, probably coarse grit, - - - - - - -	3	6
Grit, thick-bedded and coarse above, but mostly fine, red, with few pipes, - - - - - - -	14	0
Thin-bedded layers of red and light-coloured rock alternating, seen in places; many white pipes (sub-zone 4), - - - - - - - -	12	0

The remarkable outliers of quartzite which cap the three eastern spurs of An Teallach furnish evidence that the Cambrian rocks once extended much further to the west than they now do. The most northerly of these outliers on Glas Mheall Mor is an oval patch, about 130 yards long, consisting of only a portion of the lower part of the basal quartzite, with some five or six feet of the basal conglomerate. Each of the others embraces the whole of the basal quartzite, together with a small part of the pipe-rock; but much of the rock is loose and slightly out of place, and the junction with the Torridon Sandstone along the hillsides is much obscured by debris from above. In each of these detached areas the rock has the same dip as in the main mass to the eastward, viz., 15°–18°. The outlier in Sail Liath is the largest of the three, and affords the best sections, though the central one, which caps the spur called Glas Mheall Liath, presents the most striking appearance as seen from the east, whence it assumes the form of an almost perfect cone, though in reality it is only the steep extremity of a ridge, slightly higher than the part connecting it with the main mass of the mountain.

Further proof of the former westerly extension of the Cambrian formation is furnished by the detached portions of them observable in various places on the downthrow side of the large fault that passes in a S.S.W. direction through Coigach and by the entrance to Little Loch Broom. The largest of these outliers is exposed on the shore west of the Free Church, Achiltibuie (east side of Baden Bay), and lies about nine miles to the west of the main outcrop. Both the basal quartzite and the pipe-rock are here represented in their natural order, though many of the beds are much crushed, especially those of the pipe-rock which lie nearest to the fault.

Another isolated patch of quartzite may be seen near the fault west of Scoraig, on the north side of the entrance to Little Loch Broom. A third example, though too small to be marked on the map, is of sufficient interest to deserve notice. It occurs on the south side of Gruinard Bay and on the southern slope of Beinn Dearg Bad Chailleach (north-west corner of Sheet 92). Perhaps the rock should be regarded as a mass of fault-breccia, but its existence here certainly proves the former extension of the Cambrian strata at least as far west as this place. Fine white and grey siliceous grit, which is seen here in place and can be traced by fallen blocks for about 30 yards, almost certainly belongs to the serpulite-grit, while a mass of limestone, three feet long and nine inches thick, is observed in another place. These Cambrian relics are situated about 11½ miles to the west of the main outcrop of the series.

Fucoid Beds.—This sub-division maintains throughout the district its usual character of laminated or flaggy impure yellow compact limestone bands, alternating with fine compact gritty bands and layers of hard shale. It is not well exposed in the ground south of Loch Broom, but numerous sections of it, both in the unthrust and thrust areas, occur near Ullapool and in Strathkanaird. One of the best of them has been already alluded to as visible on the north side of the Ullapool River. Other good sections have been laid open by the Corry Burn, near the cloth mill south of the Braes of Ullapool, and along the shore of Loch Broom to the southward. In the latter place the dark shaly bands have been well searched several times for the *Olenellus*-fauna, but hitherto only fragments have been found.* The fucoid-beds seem to be entirely cut out under the scar called Creag Chorcurach, east of Dundonnell Lodge, the Moine-schist being thrust over the quartzite.

Serpulite Grit.—The Serpulite grit is here generally well exposed near the same places where the fucoid-beds crop out, such as many parts of the ground south of Strathkanaird and up the Ullapool River, especially on the north side. In the Corry Burn, south of Ullapool, this grit forms a single mass about 15 feet thick, which has given rise to a waterfall just below the bridge. In many places it appears as a small crag crowning the fucoid-beds. Throughout the greater part of the district all the strata above the serpulite grit have been displaced by thrust movements. South of Loch Broom, under Creag Chorcurach, the serpulite grit disappears, together with the fucoid-beds. It is also cut out by the Moine thrust for a distance of from two to three miles near Achneigie in Strath na Sheallag, about five miles south of Dundonnell Inn.

* In 1894 A. Macconochie detected fragments of trilobites together with other fossils on both sides of Loch Broom, and in various places to the north of Ullapool.

Durness Limestone.—This important member of the Cambrian series, owing to normal faults as well as to thrusts, has been isolated in several small detached areas south of Strathkanaird, but, as most of the sections are intimately connected with the thrust-movements, their description is reserved for Part IV. The largest area lies to the north of Loch na Maoile. Another extensive outcrop may be seen about Loch Ob an Lochan. Where the rock is not covered with drift it supports a short green grassy herbage, which presents a great contrast to the surrounding darker heathery ground. For some distance south of Loch Dubh, although no limestone is seen at the surface, a swallow-hole indicates its presence in at least one place. In the valley E.N.E. of Creag na Feola (north of Ullapool) the limestone again appears, and is repeated four times owing to the effect of two cross faults. The most southerly of these four exposures is cut off by a thrust which brings over it the limestone first, the Torridon Sandstone, and afterwards a complicated assemblage of other rocks, until at the extensively-denuded Ullapool valley a large area of limestone is again laid bare. The calcareous rocks are here unfossiliferous. They no doubt belong to the two lower zones—the Ghrudaidh and the Eilean Dubh—which, however, cannot well be differentiated owing to the numerous small thrusts which traverse them, and which greatly exaggerate their true thickness. Most of the limestone, which has been largely quarried and burnt for lime, is of a white colour, and probably belongs to the Eilean Dubh sub-division. Several small outcrops of the limestone are found among the thrust rocks east of Ullapool. An interesting section occurs at the bridge over the Corry Burn, three-quarters of a mile south-east of Ullapool, where a dark-grey oolitic limestone (with serpulites) is overlain by thrust Torridon Sandstone. This band extends some distance southwards, and a quarter of a mile from the bridge it is thrown up nine feet by a normal E.N.E. fault, and soon disappears under the waters of Loch Broom. No limestone is exposed beneath the thrust rocks for several miles southwards from Loch Broom, until at the principal burn east of Dundonnell Lodge (the one that issues from Loch a' Charnain Bhain) the following section is to be seen:—

Thrust Torridon Sandstone.	
Grey limestone, - - -	about 26 feet.
Serpulite grit, - - -	12 to 15 feet.
Fucoid-beds, flaggy, rather siliceous, - - -	a few feet.

Further south for many miles no trace of the Durness limestone is to be seen.

It seems probable that a fault runs along the line of Loch Broom to the south of Ullapool, having a downthrow to the north-east. The Cambrian rocks on each side of the loch have the same dip and strike, the dip being generally E.S.E. at angles of 15° to 20°. Were there no fault, any given bed should be found on the south side of the loch to the S.S.W. of the same bed on the opposite side. But, as a matter of fact, the outcrops on the south side lie almost due south of those on the north. The thrust planes and rocks between them appear also to be shifted in the same way, and the Moine-thrust, which on the east side is found at Camas an Daimh, appears on the west side far up the loch near Rhiroy, and nearly S.S.E. from its corresponding position on the other side, instead of S.S.W. as we should expect it. Confirmatory evidence has been obtained south of Inverbroom, above the head of the loch, that this valley and loch lie along a line of fault.

A little to the north of the mouth of the Corry Burn many small faults range E.N.E., and throw down north from a few inches to about two feet. Still further north several lines of rupture traverse the quartzite in the same direction. Opposite the Royal Hotel a more considerable fault runs also E.N.E., with a downthrow to the north. An east and west fault appears along the next burn, where the quartzite is much crushed. Branch faults strike off from this dislocation to the N.N.E., and are probably connected with the large fault which, crossing the Ullapool River in this direction, has a throw considerably greater than the whole thickness of the basal quartzite—not less, therefore, than 300-400 feet. This fault is one of the two that repeat the limestone east of Creag na Feola—the other being a large fault ranging E.S.E., and throwing down on the north. In Strathkanaird two large faults cross one another, and nearly repeat the curious arrangement seen east of Creag na Feola. One of these, which trends to the north-east, runs nearly along the road between Ardmair and Strathkanaird for a distance of two miles. The crushed rock which accompanies it has doubtless materially contributed to the formation of the valley in which the road runs. This dislocation must have a downthrow to the north-west of 700-800 feet, as it is considerably more than the total thickness of the quartzite. As the fault proceeds north of the river its throw becomes a good deal less, and it probably is taken in part by the east and west fault which runs nearly parallel to the valley, and which also throws down on the north, so as to bring the base of the quartzite on the south side opposite to the serpulite grit on the north side. This must be a vertical displacement of 600-700 feet.

CHAPTER XXVII.

CAMBRIAN AREA FROM STRATH NA SHEALLAG TO KISHORN.*

In the undisturbed area between Strath na Sheallag and Loch Maree, the Cambrian strata, ranging in places from the basal quartzite to the lowest members of the Durness dolomites, form a comparatively narrow belt resting on the Torridon Sandstone. In the northern part, especially between Sgùrr Bàn and Beinn a' Chlaidheimh, the discordance between the two formations is clearly displayed, bed after bed of the red sandstones being transgressed by the basal quartzites. South of Lochan Fada, however, where the observer follows a strike section for a distance of two miles, the unconformability is not very apparent, though the boundary between the two is distinctly traceable.

The members of the arenaceous series extend along the base of the eastern slope of the Loch an Nid valley, thence mounting the crests of Sgùrr Bàn and Mullach Coire Mhic Fearchair, they trend southwards to the moorland east of Lochan Fada. At that point the outcrops of the various zones are shifted south-westwards for about a mile and a half by the Fasagh fault. Beyond that lake to the Kinlochewe River they form a conspicuous crag beneath a broad mass of displaced Lewisian gneiss.

South of Loch Maree to Loch Kishorn the area occupied by unthrust members of this system is limited, as they are mostly affected by the post-Cambrian movements. But the quartzites are traceable continuously from the shore of Loch Maree through the Kinlochewe Forest to the magnificent escarpments on Ruadh-stac Mor, one of the western spurs of Beinn Eighe. Here also they rest unconformably on the Torridon Sandstone, though the discordance is not so apparent as in the Dundonnell Forest. In Glen Kishorn, the series up to the serpulite grit is seen in natural order between Rassal and Glaschnoc, but further north in the Achnashellach Forest the pipe-rock and basal quartzite soon participate in the movements.

The former extension westwards of the Cambrian strata is here indicated by conspicuous outliers of the arenaceous series at

* By B. N. Peach and J. Horne, with notes by L. W. Hinxman and E. Greenly. The district described in this chapter is contained in Sheets 81, 82, 92, Geographical Survey Map of Scotland, on the scale of 1 inch to a mile ($\frac{1}{63360}$).

some distance from the outcrop of the main belt. For example, on Beinn a' Chlaidheimh (2750 feet), south of Strath na Sheallag, on Liathach (3456 feet), at the head of Loch Torridon, and on Beinn Damph (2958 feet), there are small patches of basal quartzite, and also, in the two latter instances, a portion of the lowest zone of the pipe-rock.

In this belt one exception has been found to the apparent absence of organic life in the lower division of the quartzites, for, on the crest of the ridge between Sgùrr Bàn and Beinn a' Chlaidheimh, on the west side of Loch an Nid valley, vertical worm-casts were detected in a band of quartzite belonging to this sub-division. Another slight departure from the normal type of sedimentation of the false-bedded grits occurs in the Beinn Eighe Forest, south of Kinlochewe, where a zone of grey shale, thirteen feet in thickness, occurs near the base of this sub-group. The overlying zone of pipe-rock, from 250 to 300 feet thick, displays in the Dundonnell Forest the five sub-zones met with in the Assynt district, and they have been traced southwards through the mountainous region south of Loch Maree to Kishorn.

The feature of special importance in the belt of undisturbed Cambrian strata between Strath na Sheallag and Kishorn is the exposures of fucoid-beds and serpulite grit, which have yielded an assemblage of organic remains characteristic of the lower division of that system. A glance at the geological map accompanying this Memoir will show that the fucoid-beds form a more or less continuous outcrop through the Dundonnell Forest to Loch Maree. The locality, where the trilobite-bearing bands in this zone were first observed, and where portions of *Olenellus* were first found by A. Macconochie, occurs in Allt Righ Iain—a small stream on the eastern side of Loch an Nid valley, and about three miles E.S.E. of Loch na Sheallag. At the point where the burn is crossed by the hill-road between Dundonnell and Achneigie, the upper portion of the fucoid-beds is exposed, containing two prominent bands of dark-blue shale, intercalated in the normal dolomitic beds of the zone. The upper band lies about three feet and the lower one about nine feet from the top of the fucoid-beds. The fragments of *Olenellus* were found in the lower band, the best specimens being confined to a seam less than an inch thick. Some of these dark-blue shales are slightly calcareous, and are traversed by small worm-casts. It is highly probable that they are on the same horizon as the blue "piped" shales at the top of the section near Meall a' Ghubhais, to which attention will be immediately directed. It is noteworthy, however, that the soft shale so highly fossiliferous south of Loch Maree has not been detected in Allt Righ Iain.*

The upper limit of the fucoid-beds in this section is well defined, the base of the *Salterella* (serpulite) grit forming a small cascade over which the stream leaps on to the softer beds

* "The *Olenellus* Zone in the North-West Highlands of Scotland." By B. N. Peach and J. Horne. *Quart. Jour. Geol. Soc.*, vol. xlviii., p. 227.

below. The higher portion is charged with *Salterella* in fine preservation.

Immediately to the north of Allt Righ Iain, several interesting stream-sections present excellent exposures of the *Olenellus* shales with the characteristic organisms. One of these streams (unnamed on the six-inch map) rises on the moory watershed between Allt Coire Chaorachain (draining into Strath Beg) and Strath na Sheallag. About a mile to the north of Allt Righ Iain it is crossed by the hill-road leading to Dundonnell, whence it flows southward for two-thirds of a mile, until joined by a small tributary (Allt a Chip). Here the main stream is deflected to the south-west, joining the Loch an Nid River near the mouth of Allt Righ Iain. In the sides of a small gorge in Allt a Chip an excellent section may be seen of the fucoid-beds with the two bands of dark-blue shale near the top of the zone, separated by the normal dolomitic layers, the thickness of the upper zone being three feet and of the lower 19 inches. A layer of rusty dolomite, about a foot thick, overlying the lower band of dark-blue shale, was found to be crowded with excellent specimens of *Hyolithes* sp.

Again, in the main stream of which Allt a Chip is an affluent, both of the layers of dark-blue shale near the top of the zone are visible, the upper one cropping out at the base of a small waterfall formed by the overlying *Salterella*-grit, the latter being succeeded by black shaly limestone and dark mottled dolomite with seams charged with *Salterella*. These beds, which form the base of the Durness calcareous series, are abruptly truncated by a thrust to be referred to in the sequel. It is important to note that, in this last section, the brown dolomitic bands associated with the *Olenellus* shales contain serpulites (*Salterella*).

Further south, near Loch an Nid, fragments of trilobites were found in thin shales intercalated in the *Salterella*-grit. About 450 yards to the north of that lake, the following vertical section is exposed in an escarpment cut by a streamlet on the east side of the valley, beneath a mass of disrupted Lewisian gneiss:—

		Ft.	In.
Zone of *Salterella* Grit.	Grey quartzose grit,	18	0
	Flaggy grits, with intercalated shales,	7	0
	Grey shales,	1	0
	Dark blue shales containing *Olenellus*,	0	8
	Grey grit,	2	0
	Dark grey shales,	1	6
	Grey quartzite,	7	3
Top of Fucoid Beds.	Brown dolomitic shales with bands of dark shales,	5	3

The dark-blue shales intercalated in the grits and quartzites have yielded a carapace of *Olenellus Lapworthi* and other fragments of this form. These shales are underlain by grey grits and quartzites forming the lower portion of the zone of the serpulite (*Salterella*) grit. When traced southwards along the hill-slope, the upper and lower ledges of quartzose grit coalesce and form a prominent escarpment overlying the fucoid-beds. At certain localities along the base of the Loch an Nid crag, beneath the disrupted Lewisian gneiss and Torridon Sandstone, the undisturbed serpulite grit is overlain by the basal member of the Durness dolomite charged with *Salterella*.

By far the finest section of the trilobite-bearing bands of the fucoid-beds occurs immediately to the south of Loch Maree, about a mile from the shore of that lake.* On the northern slopes of Meall a' Ghubhais (2882 feet)—a conspicuous hill (three miles W.N.W. of Kinlochewe) formed of an outlying mass of displaced Torridon Sandstone—a streamlet rises near Loch na Mna' Bige in the thrust materials, and exposes the underlying undisturbed Cambrian strata from the serpulite grit to the basal quartzite. The fucoid-beds are seen on the west bank at the point where the 1250-feet contour-line crosses the burn, and where their outcrop is shifted by a small fault with a downthrow to the south-east. Though not far beneath the plane of the Kinlochewe thrust, the beds are not deformed nor are the fossils distorted. The various fossiliferous sub-divisions, which have been carefully worked by A. Macconochie, are given below in descending order:—

	Ft.	In.
Serpulite grit.		
7. Blue clayey and sandy shale full of small vertical worm-casts yielding occasional fragments of *Olenellus gigas* and *Olenellus Lapworthi*, - - -	18	0
6. Shale with well-preserved brachiopods (*Acrothele subsidua*), - - - - - - -	0	9
5. Dark flaggy or platy shale, with fragments of *Olenellus* at base, - - - - - - -	2	10
4. Ferruginous yellow dolomitic band, with conchoidal fracture, - - - - - - -	0	7
3. Pisolitic ironstone with remains of trilobites and echinoderms, - - - - - - -	0	2
2. Hard ferruginous dolomitic band, the bottom film crowded with carapaces of *Olenellus*, - -	0	3½
1. Soft, jointed, cleaved clayey shale. The topmost seams yield occasional complete specimens of *Olenellus* and fine examples of *Olenelloides armatus*; the lowest two inches are crowded with disjointed and broken segments of *Olenellus*. This band of shale is termed the *Olenellus* layer, - -	0	11

Dolomitic fucoid-beds are seen in stream further down.

As the foregoing section illustrates the typical development of the trilobite-bearing bands in the fucoid-beds in the North-West Highlands, it may serve a useful purpose to indicate the sub-zones which are represented beyond the limits of the Loch Maree area. The peculiar soft cream-coloured shale, blue in fresh fracture, which, from the abundance of the zonal form in certain thin films, has been termed the *Olenellus* layer, has been noted in the far north at An t-Sron on the east shore of Loch

* "Additions to the Fauna of the *Olenellus* Zone of the North-West Highlands," by B. N. Peach, *ibid.*, vol. l., p. 661.

Eireboll, on the north side of Loch Assynt near Skiag Bridge (two miles N.N.W. of Inchnadamff), on the north shore of Loch Broom, and also in Skye, in the Tokavaig Burn south of the Ord. At each of these localities specimens of the characteristic zonal form have been obtained, and at the last of these exposures in Skye examples of *Olenelloides armatus* have also been recorded. One noticeable feature is the absence or the limited development of the blue "piped" shale (Sub-zone 7 in the Meall a' Ghubhais sequence) in the various sections beyond the Loch Maree area.

The peculiar band of pisolitic ironstone with fragments of trilobites and echinoderms has likewise a wide distribution, for it has been noted by the side of the shepherd's footpath on tne south side of Loch Glencoul, by the Knockan Cliff near the southern border of Assynt, and again in the Achnashellach deer forest between Kinlochewe and Glen Carron.

In all the sections referred to above, the fragments of *Olenellus* have been found either in the *Olenellus* layer (Sub-zone 1, Meall a' Ghubhais section) or in bands overlying that horizon, but at one locality along the line between Eireboll and Skye they have been noted below that stratigraphical position. In the Ullapool River a carapace of *O. Lapworthi* was obtained in a thin seam of grey shale interleaved in flaggy dolomitic beds, presenting the normal characters of the lower portion of the zone. It is worthy of note also that, in most sections, the sandy dolomites beneath the *Olenellus* layer contain *Salterella* and *Hyolithes*.

The distribution of the Cambrian strata in the displaced masses between Strath na Sheallag and Kishorn is extremely irregular. In the Dundonnell Forest and southwards to the Heights of Kinlochewe they appear as thin lenticles traceable for no great distance. Beyond that locality, in the lower part of Glen Bruachaig, the folded and thrust zones of the pipe-rock and fucoid-beds, rising from underneath the mass of Lewisian gneiss that overlies the Kinlochewe thrust-plane, are well displayed on the west side of the valley, and the fossiliferous zones are not much deformed. In particular, the cleaved fucoid-beds visible in the channel and on the banks of that stream about a mile and a half below the Heights of Kinlochewe contain the pisolitic ironstone band and the soft shale beneath, from which carapaces of *O. Lapworthi* and *Hyolithes* have been obtained. Again, among the materials above the Kinlochewe thrust-plane, striking evidence has survived of the double unconformability of the basal quartzite on the Torridon Sandstone and Lewisian gneiss.

South of the Kinlochewe River, on Beinn Eighe, the Cambrian strata, repeated by numerous folds and thrusts, cover a belt of ground about three miles broad (Part IV., Chapter XXXVII.). Beyond that locality, from the head of Glen Torridon southwards by Beinn Liath Mhor towards An Ruadh-stac, they appear as long parallel strips amid intervening belts of Torridon Sandstone, which furnish impressive testimony of the extensive folding, thrusting, and denudation of the strata. (See Geological Map.)

Along the eastern margin of the Coulin and Achnashellach deer forests, from Loch Clair to Achnashellach Station, thence by the hill-slopes on the west side of Glen Carron to Glen Kishorn, the quartzites, fucoid-beds, and serpulite-grit can be traced more or less continuously to the west of the outcrop of the Kinlochewe and Kishorn thrust-plane. In Allt nan Dearcaig, about a mile and a half to the north of Achnashellach Station, the band of pisolitic ironstone is well seen in the exposure of fucoid-beds. Towards the southern part of this belt, in Glen Kishorn and along the north-west slope of Sgorr a' Gharaidh, there is a prominent development of the two lowest zones of the Durness dolomites and limestones.

CHAPTER XXVIII.

CAMBRIAN ROCKS IN THE ISLAND OF SKYE.*

The Cambrian rocks of Skye are confined to the neighbourhood of Ord and the district between Broadford Bay and Loch Slapin. The total area occupied by them is less than ten square miles. The different divisions here represented are as follows:—

Cambrian limestone and dolomite.	Ben Suardal limestone. Probably homotaxial with the Balnakiel or Croisaphuill zone of Sutherland. Strath Suardal and Beinn an Dubhaich limestone. Sangomore limestone (?). Sailmhor limestone. Eilean Dubh ,, Ghrudaidh ,,

Serpulite grit.
"Fucoid" shales, including thin bands of limestone.

Quartzite.	Upper quartzite or pipe-rock, divisible into many zones. Lower or false-bedded quartzite.

All the exposures of these rocks have probably been driven forward by the great post-Cambrian thrusts, but in some cases such displacement cannot be proved, though the strata have been sharply folded. One instance of a possibly unthrust condition extends from Coill' a Ghasgain to Loch Eishort, and includes the quartzite, the fucoid shales, the serpulite grit, and part of the Ghrudaidh limestone.

Quartzite.—Near Ord the quartzite forms little hills, about 900 feet high, the whiteness of which contrasts strongly with the brown or red tints of the adjacent Torridonian rocks. The largest mass, which includes both Sgiath-bheinn an Uird and Sgiath-bheinn Chrossavaig, is a little more than three miles in length from N.N.E. to S.S.W. It is divided by thrusts into different portions, all of which belong to a single inlier which has once been covered by rocks brought forward on a more important thrust-plane. This plane has been folded into an anticline, and the rocks below certain parts of it have been exposed by denudation.

West of this inlier another band of quartzite runs from Sgiath-bheinn Tokavaig to the coast of Loch Eishort, and then forms a chain of islands across the loch, on the northern side of which it emerges, but is soon concealed under Mesozoic rocks. This band likewise forms part of an inlier which has once been covered by rocks thrust over it, and the overlying thrust-plane has also been folded into an anticline. The sedimentary rocks seen above the thrust-plane are all Torridonian, except at the

* By C. T. Clough. A few paragraphs have been supplied by A. Harker. The district described in this chapter is included in Sheet 71 of the Geological Survey Map of Scotland, on the scale of 1 inch to a mile ($\frac{1}{63360}$).

coast near Ord, where various small exposures of the lower quartzite and other Cambrian rocks appear above that plane. The quartzite is seen every here and there on the foreshore W.S.W. of Ord as far as the north side of Ob Gauscavaig, while on Eilean Ruairidh a considerable exposure shows the junction of the lower and upper quartzite.

Between Loch Eishort and Loch Slapin an area of quartzite, about 500 yards long and 100 yards broad at its greatest width, rests on Torridon Sandstone, and the two rocks are cut off on the north side by a normal fault that brings up the Cambrian limestone. On the south side they are unconformably overlain by the conglomerate at the base of the Mesozoic rocks.

Another patch of quartzite occurs in Allt Beinn Deirge, south-east of Beinn na Caillich, just above the sharp bend of the stream where it emerges on the open strath. Torridon Sandstone, doubtless an outlier above the Ben Suardal thrust, is exposed in the stream for about 100 yards, and is accompanied for perhaps 20 yards by basal quartzite, which is conglomeratic, and must represent the base resting on the Torridonian rocks.

At the bottom of the lower quartzite the pebble bed or conglomerate is generally to be seen, never more than five or six feet thick, and sometimes only a few inches. Its pebbles are here chiefly of quartz. In one section on the east side of Sgiath-bheinn Chrossavaig (two miles north-east of Tarskavaig), where it is about five feet thick, its pebbles are as large as beans and walnuts, but in other sections near this the conglomerate is much less coarse. The thickness of the lower or false-bedded quartzite may be about 330 feet.

The upper quartzite or pipe-rock contains "pipes" in all the beds, and its sub-divisions found in Sutherland hold good in Skye. It is seen in its least-disturbed condition on the coast at Rudha Dubh Ard (Loch Eishort), where the following zones may be made out:—

6. Top rock of a white or reddish-grey colour. Often rather coarse-grained and friable. Occasional pipes with mouths three inches in diameter. 20 feet.
5. Alternating massive and thinner bands. The general colour is Indian red, but the pipes themselves are white. 20 or 30 feet.
4. Trumpet pipe-rock. White or dirty-white in colour; usually massive near the top. The mouths of the pipes vary much in diameter, some being less than a quarter of an inch wide, while others are as much as three inches. In the larger examples the mouths are oval, and the diameters decrease rapidly downwards. The bedding surfaces are often rippled, and the rock is false-bedded. About 55 feet.
3. Massive pink pipe-rock. Many of the quartz-grains are red at the outsides. In the bottom beds, about 10 feet thick, the mouths of many of the pipes are only $\frac{1}{16}$-inch in diameter. About 55 feet.
2. Massive white pipe-rock. Pipes average a quarter of an inch in diameter, and are often closely crowded. About 35 feet.
1. Small pipe-rock. Pipes not usually more than $\frac{1}{8}$-inch in diameter, generally of a purer white colour than the rest of the rock. Ripple marks common, and the rippled surfaces may for several square yards show no pipes. 50 or 60 feet.

The total thickness of the upper quartzite may be estimated to be about 270 feet.

In Ord River, nearly a quarter of a mile south-west of Teampuill Chaon, the line between the quartzite and the fucoid-beds is not sharply defined. At the top of the quartzite a soft reddish-brown grit contains small dark-green grains of glauconite (?). In specimen No. 7356, induration is seen to have been effected by secondary enlargement of the quartz grains, which had been coated with ferric oxide before the enlargement took place. The layer of ferric oxide is not usually continuous round the entire outline of a grain, but may include many grains. The areas enclosed by it are much too complicated in form to represent pebbles of a composite rock. The floor on which the quartzite was deposited presents a smooth surface of Torridonian (Applecross) rocks. The difference between the dip of the two formations in Skye is not striking, and in most sections is hardly noticeable.

No cleavage has been observed in any part of the quartzite of Skye, nor any noticeable drag of the pipes out of their original vertical position. But near some of the thrusts, particularly in the south-eastern part of the quartzite between Ord River and Loch Eishort, over extensive areas the chief planes are joints and faces of fine crush.

Fucoid-beds.—On the west side of Sgiath-bheinn an Uird this sub-division comes in conformably over the quartzite, and can be traced in a north-north-easterly direction to Loch Eishort and south-westwards to within a mile of the Ord River. For some distance on either side of this river the outcrop is cut out by a thrust, but the band reappears again on the west side of Sgiath-bheinn Chrossavaig, and continues for nearly three-quarters of a mile further south. A little west of each of these outcrops the beds are repeated by minor thrusts. West of the quartzite of Sgiath-bheinn Tokavaig (two miles north-east of Tarskavaig) and Rudha Dubh Ard, the fucoid-beds again occur in conformable sequence above the quartzite, but for some distance south of the Rudha they are considerably disturbed. In, and for a little distance south of, Ord Bay various exposures of this sub-division may be seen on the west side of the Cambrian limestone. They lie between two thrust lines, which appear to unite as they go south. The fucoid-beds display their usual tendency to form smooth grassy ground. Between Sgiath-bheinn Tokavaig and Cnoc an Uairidh they have given rise to a conspicuous hollow between the harder outcrops of quartzite and serpulite-grit.

A quarter of a mile S.S.W. of Rudha Dubh Ard the quartzite is immediately followed by brown-weathering sandy shales, about 30 feet thick, mixed with thin yellow calcareous flags, and covered by greenish-grey or bluish-purple shales and thin brown sandy bands. There is no black shale. This upper division seems to be as much as 50 feet thick, but perhaps some parts of it are repeated by obscure thrusts. On the north side of Ord River the total thickness of all the fucoid-beds does not seem more than 60 feet.

In many places the lower part of these beds includes one or two bands of limestone, which weathers with a deep-brown colour, but is pale-pink when fresh. A specimen taken from one of these bands half a mile south-west of Sgiath-bheinn an Uird has a specific gravity of 2.82. Between two-thirds and three-quarters of a mile south of Teampuill Chaon (about two and a half miles north-east of Tarskavaig) a limestone appears with a thickness of about six feet, and lying 12 or 15 feet above the top of the quartzite. In a burn a little further south-east only eight or nine inches of limestone are observable, overlain by brown sandy shales mixed with calcareous gritty bands. In Ord River, about a quarter of a mile above the foot, two limestones crop out, one of which is ten feet thick.

Fucoid-like markings are well seen on the hillside a little more than half a mile south-east of Sgeir Gormul (Loch Eishort), by the roadside 250 yards S.S.W. from the bridge at the foot of Ord River, and also in the burn three-quarters of a mile south of this foot. A. Macconochie has proved the presence of the *Olenellus* fauna in the fucoid-beds near Ord, and in the burn about three-quarters of a mile south of the mouth of Ord River. In the shale exposed at low water in the bay a quarter of a mile S.S.W. of Ruhda Dubh Ard he failed to find the *Olenellus* layer, but from a thin hard ferruginous band he collected a fragment of a trilobite and specimens of *Hyolithes*. No cleavage has been detected in any of the fucoid-beds of Skye.

Serpulite (*Salterella*) *Grit.*—The largest outcrop of this subdivision comes conformably above the fucoid-beds and quartzite of Sgiath-bheinn Tokavaig and Cnoc an Uairidh (one-third of a mile east of Ord). Another exposure, on top of the fucoid-beds, extends from the sea coast 1000 yards E.S.E. of Sgeir Gormul to a third of a mile south-west of Sgiath-bheinn an Uird. A little west of this outcrop others make their appearance owing to repetition by minor folds. In, and a little south of, Ord Bay an obscure thrust patch of fucoid-beds and serpulite-grit lies between the limestone and the lower quartzite.

The serpulite-grit is of much the same character in Skye as in Sutherland, except that serpulite-remains seem here to be rarer, distinct remains of these organisms having only been detected in one place—an exposure near the middle of Ord Bay. About 700 yards slightly west of south of Rudha Dubh Ard the grit contains marks resembling the mouths of large pipes. A quarter of a mile E.N.E. of the mouth of Ord River the thickness of the serpulite-grit is about 50 feet.

The Calcareous Series.—The limestone occurs in Skye near Ord and near Broadford. Dr. Macculloch, in 1815, after an investigation which he states "was attended with more labour and doubt than that of all the other rocks of Sky," finally decided that it was an altered form of the Secondary limestone*, in the neighbourhood of which it is frequently seen; but for years afterwards a keen controversy raged regarding its true

* "A Sketch of the Mineralogy of Skye," *Trans. Geol. Soc.*, vol. iii., p. 1.

character, and it was not until 1888 that Sir A. Geikie finally proved its Palæozoic age by finding fossils in it.* The outcrops of this part of the Cambrian formations near Ord do not cover so much as a square mile, but show three or four of the lower divisions into which the calcareous series is divided. The chief outcrop extends from the islands on the west side of Rudha Dubh Ard in a southerly direction past Ord. Its length, including the islands, is rather less than two miles, and its average breadth a quarter of a mile. The western boundary is formed by the western limb of a folded thrust-plane, along which both the Torridonian and the Cambrian rocks have been driven over the limestone. In most places on the east and south-east sides the outcrop comes conformably above that of the serpulite-grit. The rock-mass now referred to has itself been thrust over another rock-mass, in which other outcrops of the limestone appear on the north side of Ord River, considerably disturbed with folds and thrusts.

The limestone in the Broadford district occupies an area of perhaps five or six square miles, and extends in an irregular curve from Torran, near the head of Loch Slapin, through Strath Suardal and Ben Suardal and Coire-chat-achan to the Sound of Scalpay. Between Loch Slapin and Ben Suardal there comes up in the middle of the limestone, and occupying approximately the centre of an anticline in it, the great intrusive mass of granophyre which forms Beinn an Dubhaich. The area between Beinn Caillich and Camas na Sgianadin is also riddled with intrusions, partly of granophyre and partly of gabbro.

On the north side of Ben Suardal the boundary of the limestone is a thrust-plane on which the Applecross grits of the Torridonian series have been pushed over the limestone. This major thrust has been folded into an anticline, with axial plane striking N.N.E. Whether the whole of the limestone is lying on another lower major thrust is not certain, but there are undoubtedly minor thrusts, and also sharp isoclinal folds, within the limestone.

The limestone is exposed in coast-sections at the west end of the Broadford district around Torran. In Strath Suardal a considerable extent of low ground is covered by dreary peat mosses and alluvium. Macculloch † noted this barren, uncultivated tract as being singularly unlike the type of country usually seen in limestone areas.

The limestones of the Broadford district have been more sharply folded and more deformed than those of Ord. Two hundred yards east of Ben Suardal a dark granular limestone is isoclinally folded along axial planes that sometimes dip E.S.E. at 23°, and the under-limbs are the most thinned. On the hillside 350 yards south-east of Ben Suardal, and in other places, a

* "On the Altered Limestones of Strath, Skye," *Quart. Jour. Geol. Soc.*, vol. xliv., p. 62.

† "Western Isles of Scotland," vol. i., pp. 287-288.

close strain-slip cleavage dips steeply south-east. On the north-west side of Loch Lonachan, 700 yards S.S.W. of the outlet, the small black chert lumps in the limestone have been dragged out into trains of granules at right angles to the strike, and some of the fossils (*Maclurea*) have been elongated in the same direction. A third of a mile north of Ben Suardal the worm-casts in the limestone are elongated in a W.N.W. direction.

In the Ord district no cleavage has been observed in any part of the limestone, but in many places the rock is crossed by thin strings of calcite without any general direction: such strings are particularly abundant near the foot of Ord River. The sub-division representing the Ghrudaidh limestone of Sutherland spreads over a large space on the hillside half a mile north-east of Sgeir Gormul (Loch Eishort). Better sections, however, occur on the hillside north-east of Ord, and in the burn about 1500 yards slightly west of south of Ord. A calcareous grit, a few inches thick, sometimes comes between the serpulite-grit and the limestone. The bottom bed of limestone—in places about 25 feet thick—contains small grains of quartz, like those in the grit below, and weathers with a deeper brown colour than the overlying limestone. No distinct remains of serpulites have been noticed in it. Its texture is coarsely granular, and the specific gravity of a specimen taken from about 350 yards south-east of Ord proved to be 2.84, a figure which implies a considerable amount of dolomitisation. This basal band is surmounted by the main mass of the sub-division, which is a granular leaden-coloured limestone, with specific gravity ranging from 2.815 to 2.83, and a thickness of about 65 feet. Above it lies an alternating series of granular and more compact bands, the latter closely resembling the general type of the Eilean Dubh group of Durness. Some of the granular beds are soft and crumbly, and oolitic in structure. The oolitic grains are sometimes preserved in chert, and project on the weathered faces of the rock, but the cherty bands are never thick, and do not seem to consist of such pure chert as that of the chert lumps in the Eilean Dubh limestone. The specific gravities of two specimens of the oolitic limestone were each determined to be 2.83. The line between the Ghrudaidh and the Eilean Dubh divisions is not sharply defined, and it may possibly have been drawn at slightly different horizons at different localities. On the hill 350 yards south-east of Ord the total thickness of the Ghrudaidh group as here developed is estimated at about 115 feet.

The representative of the Eilean Dubh group of Durness covers more ground than any other of the limestone divisions near Ord, and is probably much the thickest. It is laid bare in coast-sections north and north-east of Ord, while good exposures may be seen inland half a mile north-west and three-quarters of a mile W.S.W. of Sgiath-bheinn an Uird, on the hillside south-east of Ord, and in the wood three-quarters of a mile slightly west of south of Ord. Most of the beds in this group are flaggy, of a white or cream colour and compact texture, but mixed with these there are others of leaden colour and coarser grain. On some horizons the compact rocks are finely laminated, as in the lower half of the group on the shore a third of a mile N.N.E. of Ord, and in the upper half on the shore about 300 yards slightly east of north of Ord. Certain of the laminæ contain clastic grains of quartz, and some are of a purplish-red colour, perhaps due to staining. The specific gravities of various cream-coloured specimens were found to vary between 2.81 and 2.85.

Lumps and bands of chert occur in abundance in the lower part of the group. They are well seen in the north bank of Ord River, about 300 yards above the foot. One of the cherty beds here is two or three feet thick, but only half of it consists of chert, which occurs in bands and nodules from half an inch to two inches thick, embedded in limestone of the common type. The colour of most of the chert is pale-grey or brown, but some parts are almost black and others red. Other courses of chert, two inches and three inches thick, occur just above this bed, and also below it at intervals down to the Ghrudaidh limestone. One of the lower courses shows an oolitic structure. Another is brecciated, though the adjacent limestone is not so. The central part of the group is comparatively free from chert, though in places—for instance, in the cliff 350 yards N.N.E. of Ord—some thick bands of it may be observed. The upper cherts appear in the coast near Ord, for 50 or 60 feet below the line taken as the top, and also two-thirds of a mile slightly east of south of Sgeir Gormul. The group presents no sharply-defined upper limit. On the hillside near Ord its thickness seems nearly 500 feet, but most of the beds are so much alike that any repetition of them by dislocation could not be readily noticed.

The representative of the Sailmhor limestone occupies three areas—one on the hillside two-thirds of a mile slightly east of south of Sgeir Gormul, another on Eilean Dubh, and a third, of considerable size, east and south of Ord Bay. The best sections are those on the coast to the north-west of Ord, and a little inland to the S.S.W. of that place. The limestone of this group is granular, and in most parts of a leaden colour, but other parts are pale buff. Chert is abundant in it, and occurs in bands and lenticles, some of which are more than a foot thick. The chert bands are composed of laminæ of different colours—dull red, brown, pale grey, or dark grey, and the laminæ sometimes show an arrangement resembling false-bedding. One specimen of the limestone gave a specific gravity of 2.85, while another showed 2.83. On the supposition that no thrust repeats the strata, the thickness of the Sailmhor group in the area east and south of Ord Bay appears to be about 270 feet.

An obscure exposure, which may possibly represent a portion of the Sangomore limestone of Sutherland, has been noted on the west side of the Sailmhor limestone in the wood 700 yards

S.S.W. of Ord. It is of a white colour, granular, and contains bands of white chert as much as two or three feet thick. Two specimens gave specific gravities of 2.80 and 2.84 respectively.

In certain areas of the Broadford district the Cambrian limestones admit of being divided into three divisions, which may be named as follows, after places where they are well seen:—

Ben Suardal limestones, containing many small black cherts, and some fossils.

Strath Suardal limestone, with cherts which resemble sponges in shape, but which do not apparently show any organic structure.

Beinn an Dubhaich limestone, with ball-like structures, each composed of a number of concentric rings.

The order in which the divisions are here placed is not meant to imply that the lowest is the oldest, but it agrees with the order of superposition which is at present most usual, and which existed in the Beinn an Dubhaich area at the time of the intrusion of the granophyre. The middle division, the Strath Suardal limestone, does not appear in all the localities where we should expect it. Its absence may possibly be explained in two different ways. Either it has been concealed by the agency of obscure thrusts, which have had the effect of pushing the Ben Suardal limestone over it, or else it and the Beinn an Dubhaich limestone are merely one division of limestone, which has been altered in different places to different degrees by contact metamorphism. On the latter supposition, the Beinn an Dubhaich limestone represents the most-altered portion of the division.

The Beinn an Dubhaich limestone occupies a considerable area on the north-east, north-west, and south-east sides of the Beinn an Dubhaich granophyre, and in the vicinity of Torran. It is always in a highly metamorphosed condition, and is generally called the Strath marble. It is said to have been used for ornamental purposes in Armadale Castle, the Palace of Versailles, and the Vatican.

On the east side of the burn rather more than a quarter of a mile S.S.W. of Suardal, the spheroidal or oval forms in the limestone are well seen. The cross-sections show a succession of concentric rings, each of which projects slightly on the weathered face from the intervening substance, and is of a pale buff colour. Sometimes ten or twelve rings can be counted in the breadth of an inch. In the middle of many of the forms the centre projects on the weathered face, and consists partly of an aggregate of malacolite crystals, and partly of chert or quartz in a crypto-crystalline condition. The boundary between the Beinn an Dubhaich and Strath Suardal limestone is not well defined. The rings gradually diminish in width, and show in their centres forms which, towards the Strath Suardal limestone, are generally larger and more sponge-like.

In the old quarry half a mile south-east of Cill Chriosd (two and a half miles east of Torran), the ring structures contain a soft green serpentinous substance in concentric laminæ near their centres. In the quarries three-quarters of a mile S.S.W.

of Kilchrist (Cill Chriosd) similar serpentinous laminæ occur in a more prominent manner, and with the intervening carbonate layers they give rise to appearances which closely resemble *Eozoon Canadense.* Messrs. King and Rowney* have described these Eozoon-like structures, and they find in them close similarities to the Archæan examples.

Many samples of the Beinn an Dubhaich limestone have been weighed. They give specific gravities varying from 2.71 to 2.86. The exposures which seem the most altered by the granophyre usually give low figures, and are not magnesian. The less-altered rocks must be partially dolomitised.

The largest area of the Strath Suardal limestone lies between Loch Cill Chriosd (Kilchrist) and Coire-chat-achan. It is a mile long and two-thirds of a mile broad at its widest part, and has other smaller exposures a little way to the north-west of it. The limestone, also, forms a thin band north-north-west and another north of Beinn Suardal, and appears in these places to be lying over the Ben Suardal limestone. It has not been found with its normal characters anywhere north-west of the granophyre of Beinn an Dubhaich, nor in the Torran district.

Most of the rock weathers with a dark-grey, almost black, colour, is coarsely granular, and of a specific gravity varying between 2.82 and 2.83. In some places white and compact beds pass quickly along the strike into dark granular limestone. The change is well seen about 1000 yards slightly west of north of Ben Suardal, where rows of sponge-like forms can be traced along the strike from a dark granular into a white compact limestone: the specific gravity of a specimen of the dark limestone is 2.84, while that of the white limestone is 2.64.

The sponge-like forms project from weathered faces, and are sometimes only attached to them by very narrow connections. They are irregular in shape, but sometimes in the form of oval bodies connected by narrow constrictions, and with the long axes parallel to the bedding. They sometimes coalesce into bands several feet long, but individual oval forms do not exceed five or six inches in length, and most of them are much smaller. The outsides are usually covered with a thin coat of dove-coloured talc (?), within which comes a layer, often from a quarter to half an inch thick, of colourless tremolite needles disposed nearly at right angles to the adjacent surfaces. In an exposure about 1000 yards W.S.W. from Loch Lonachan outlet, bits of saccharoidal marble, or of a serpentinous substance, may be seen inside the tremolite layer. In some places the material of the sponge-like forms seems to consist mainly of malacolite. Half a mile north-east of Ben Suardal the centres of the forms are of chert, and some of the chert is granulitised and traversed by little veins of calcite and tremolite.

Rather more than a third of a mile east of Ben Suardal a white

* "On the so-called Eozoonal Rock," *Quart. Jour. Geol. Soc.*, vol. xxii., p. 185.

limestone, without either sponge-like forms or chert-lumps, comes between the mass of the Strath Suardal and the Ben Suardal limestone. Lenticles and bands of white chert are also intimately mixed in the Strath Suardal limestone in the area between Loch Cill Chriosd and Coire-chat-achan.

The Ben Suardal limestone forms most of Ben Suardal and a large area near Torran, and is well exposed on the coast near the latter place, as well as in crags north and north-east of Ben Suardal. It occupies a larger area than either of the other sub-divisions in the Broadford district, and is probably the thickest, but never more than one side is seen—probably the bottom—of the mass. The exposures are complicated with isoclinal folds and thrusts, but the thickness of this limestone is probably at least 200 feet. The rock generally weathers with a pale-grey colour, but the freshly-broken rock is dark-grey. Excepting when much altered, the texture is finer than that usual in the Strath Suardal limestone, and its specific gravity is lower, ranging between 2.71 and 2.76. The freedom from dolomitisation is not due to any accident of position, and the rock must by nature be less liable to dolomitisation than are the other sub-divisions. Again and again, when the Strath Suardal and the Ben Suardal limestones come together, the former is magnesian and the latter is not.

Small lumps and courses of black chert, usually from half an inch to an inch thick, are abundant in most of the beds, and mixed with these are worm-casts—small flattened tubes crossing one another in all directions and weathering with a pale-grey or buff colour. Both cherts and castings project from the weathered rock, but the former more than the latter.

Certain bands in the limestone contain, besides various small sponge-like forms, an assemblage of other fossil-remains which closely resembles that found in the Balnakiel and Croisaphuill limestones in Durness*. The best localities for fossils are the following:—The eastern slope of a bare hill nearly half a mile N.N.E. of Ben Suardal; the west side of Allt a' Mhuilinn, a little more than 1000 yards E.N.E. of Ben Suardal; the north-west side of Loch Lonachan, rather more than 700 yards and half a mile south-west of the outlet; and the coast near Torran. At the first-mentioned locality the fossils are found not more than a few feet from the Strath Suardal limestone. The exact stratigraphical positions of the fossiliferous beds at the other places are not certain. None of the other exposures lie near the Strath Suardal limestone.

About 700 yards slightly north of west from the outlet of Loch Lonachan a laminated band appears, containing oolitic structures, some of which are nearly as large as peas. The specific gravity of a specimen of the band was found to be 2.82. The position of this rock is not far above the supposed base of the

* Sir A. Geikie published in 1888 (*Quart. Jour. Geol. Soc.*, vol. xliv., p. 69) a list of fossils which were determined by Mr. George Sharman.

limestone. In certain areas the limestone has been altered into a coarse saccharoidal marble containing needles of tremolite and prisms of malacolite. About 600 yards S.S.W. from Ben Suardal the little prisms and needles, and also the long axes of the calcite grains, display a general parallelism, and it may be conjectured that the minerals formed by contact metamorphism have followed an arrangement of the materials given at the time of the thrusting and folding.

CHAPTER XXIX.

POST-CAMBRIAN IGNEOUS ROCKS OF OLDER DATE THAN THE GREAT THRUST-MOVEMENTS OF THE REGION—THEIR DISTRIBUTION.*

I. Assynt.

The remarkable development of igneous rocks associated with the Torridon Sandstone and Cambrian strata in Assynt, Sutherlandshire, aroused the attention of several of the older observers, who recognised the intrusive character of some of these masses and the contact metamorphism which they produced. In 1856 and again in 1860, Nicol noted the conspicuous sill of greenstone in the cliff of limestone south of the Inn at Inchnadamff and the large intrusion of igneous material, which he termed felspar-porphyry, near Loch Borrolan. He further observed that the Canisp porphyry not only breaks through the quartzite overlying the Torridon Sandstone, but forms a mass more than a mile in diameter in the quartzite within a few hundred yards of the Inn at Inchnadamff. From these facts he correctly inferred that the igneous intrusions must have been later than either the red sandstone (Torridon) or the quartzite.†

Confirmatory observations were made by Murchison, who, in 1859, called attention to the band of syenitic greenstone intercalated in the grey limestone about a mile west from Inchnadamff, which, though apparently regularly bedded, had, in places, converted the overlying rock into a crystalline marble. The igneous rocks in the east of Assynt near Loch Borrolan, though termed porphyries, were regarded by him as syenites, that break through the quartzites far above the limestones of that region.‡

Special attention was given to the lithological characters and distribution of these rocks by Professor Heddle, who published the results of his researches in various papers in the *Mineralogical Magazine* from 1881 to 1884.§ He regarded the Canisp

* By B. N. Peach and J. Horne, with notes supplied by W. Gunn, C. T. Clough, and L. W. Hinxman. The district described in this chapter is comprised in Sheets 101, 102, 107, and 108 of the Geological Survey Map of Scotland, on the scale of 1 inch to a mile ($\frac{1}{63360}$).

† *Quart. Jour. Geol. Soc.*, vol. xiii., p. 25, and vol. xvii., p. 99.

‡ *Quart. Jour. Geol. Soc.*, vol. xvi., pp. 221 and 232.

§ *Mineralog. Mag.*, vol. iv., pp. 233, *et seq.*; vol. v., pp. 136 to 144, 144 to 295.

intrusion as one of the most striking porphyries of Scotland, and noted the occurrence in it of porphyritic crystals of orthoclase with albite and augite. He referred to the distribution of the igneous rocks in the quartzites and dolomites in the neighbourhood of Inchnadamff, and indicated the varieties from the Canisp porphyry to the more basic types found in the calcareous series, in which hornblende is more abundant. He took exception to the application of the term porphyry to the igneous intrusion of Loch Borrolan, as it does not possess true porphyritic structure, but consists essentially of two ingredients, felspar and quartz. While indicating the localities of the marbles, he noted the important fact that they are all more or less contiguous to the mass of red felspar rock on Cnoc na Sroine or its branches, and he inferred that the marble is merely a portion of the limestone series of Assynt. Unfortunately, he somewhat impaired the value of these correct observations by suggesting that the red rock of Cnoc na Sroine is a mere variety of the "Logan Rock," which, in the localities referred to by Professor Heddle, has been proved beyond doubt to be a portion of the Lewisian gneiss.

Subsequently Dr. Callaway* alluded to some of the igneous rocks in the Assynt series, particularly between Ledmore and Loch Ailsh, noting the granitoid texture which is characteristic of the Loch Borrolan mass, and an exceptional garnetiferous variety on the slope north of the road east of that lake. In an appendix to Dr. Callaway's paper, the microscopic characters of some of these rocks were described by Professor Bonney.†

In 1886 Dr. Teall described the characters of some hornblende-bearing rocks of this series near Inchnadamff, arranging them in three groups and giving analyses of three specimens. Regarding the most basic type, which differs from the others in containing a large amount of colourless pyroxene, the author remarked that "in all probability the pyroxene is a nearly pure lime-magnesia bisilicate, and one is therefore tempted to ask whether it may not be due to the absorption by the igneous magma of a certain amount of the dolomitic limestone into which the rock has been intruded."‡ In 1892 Dr. Teall gave a detailed petrographical account of a group of rocks which he termed borolanites, obtained in the neighbourhood of Cnoc na Sroine, in the course of the Geological Survey of the district. He described the typical rock as a granular aggregate of orthoclase and melanite, with biotite, pyroxene, alteration products after nepheline and sodalite, with sphene and apatite, as subordinate and variable constituents. He pointed out the affinities of borolanite to the elæolite-syenite family, the nearest allied rocks being the elæolite-syenites of the Christiania district, investigated by Professor Brögger.§

* *Quart. Jour. Geol. Soc.*, vol. xxxix., p. 409.
† *Quart. Jour. Geol. Soc.*, vol. xxxix., p. 420.
‡ *Geol. Mag.*, 1886, p. 386.
§ *Trans. Roy. Soc. Edin.*, vol. xxxvii., Part I., p. 163.

The crystalline rocks illustrating this phase in the geological history of the North-West Highlands are all intrusive, no contemporaneous volcanic materials having been detected within the area examined by the Geological Survey. They occur (1) as plutonic masses, (2) as intrusive sheets, and (3) as dykes.

It is noteworthy that this outbreak of igneous activity in these ancient sedimentary systems has a comparatively local development. Although the Torridon Sandstone and the overlying Cambrian strata can be traced continuously for a distance of 90 miles across the counties of Sutherland and Ross, the rocks now to be described are confined to a limited portion of this belt. In the area lying immediately to the west of the post-Cambrian terrestrial movements, they extend from Loch Assynt to near Elphin, a distance of about nine miles, but in the region affected by these movements they stretch from near Beinn Lice, about a mile south of Loch More, to Ullapool—a distance of 27 miles. Originally they must have penetrated far to the east, for they have been carried westwards with the associated sedimentary strata along the higher thrust-planes. It is worthy of note also that deformed igneous rocks allied to some of the members of this series have been recorded from the shore of Loch Broom and east of Kinloch Ailsh, where they are intercalated in the Moine schists. Seeing that the dolomites of the Durness series have been converted into marble by these igneous rocks, and that the intrusive sheets are truncated by the numerous thrusts or lines of displacement traversing the region, it is obvious that the period of igneous intrusion to which they belong is later than the Cambrian dolomites and older than the post-Cambrian movements.

i. *Plutonic Mass of Cnoc na Sròine and Loch Borrolan.*

The igneous material attains its greatest development in the southern portion of Assynt, where it covers an area five miles in extent from Ledbeg eastwards to a point near the road leading to Loch Ailsh. It is traceable also from the peat-clad moor south-east of Loch Borrolan northwards to the slopes of Sgonnan Mor.

Along the north-western and western margin of the plutonic rocks near Ledmore, Ledbeg, and Cnoc-an-Leathaid-Beg, their relations to the marble are complicated by the occurrence of various outliers of materials resting above the Ben More thrust-plane, originally continuous, but now forming isolated patches, which cover portions both of the igneous rocks and of the marble. The prominent escarpment that skirts the range of hilly ground from Loch Borrolan to the west slope of Cnoc na Sroine does not mark the western limit of the mass, for the igneous rocks occur in association with the marble in the Ledbeg River and high up on the slope of Cnoc-an-Leathaid-Beg to the west. At the latter locality both the granitoid rock and the marble are buried underneath the basal quartzites and the pipe-rock, which, resting unconformably on a slice of Lewisian gneiss, form together with it an outlier separated by denudation from the displaced masses that come above the Ben More thrust-plane.

Along the northern margin the boundary-line sweeps eastwards by the south side of the Ledbeg River to Ruighe Cnoc, two miles east of Cnoc na Srôine, where there is a fine escarpment of the syenite. For most of this distance the junction of the intrusive mass with the thrust Cambrian strata is buried under peat and drift. Typical examples of borolanite occur at the margin of the mass and within a short distance of the marble on the south side of the Ledbeg River, and not far from the shepherd's house at Loyne. Again, on the south-west slope of Sgonnan Mor, four small streams, which unite to form an important tributary of the Ledbeg River at Luban Croma, display excellent sections of borolanite penetrating the marble between the 1000 and 1250 feet contour-lines. Not far above this level both the marble and the intrusive rocks are truncated by the Ben More thrust-plane, which has brought forward a great slice of Lewisian gneiss covered unconformably by Torridon Sandstone and Cambrian strata.

The eastern limit of the plutonic mass can be approximately defined by means of rocky knolls that project through the peat and drift in the neighbourhood of Strathsheaskich, near Loch Ailsh, where the igneous rock is bounded by massive white marble, apparently resting upon it, and dipping towards the east at angles from 30° to 70°. This boundary can be traced through the gap close by the Kinlochailsh road to the high road leading to Inchnadamff.

The southern limit of the igneous mass is to a large extent obscured by the extensive covering of peat which stretches continuously from the Kinlochailsh road westwards to Loch Urigill and Ledmore, but occasional exposures of rock are to be found in the streams that cut through the peat and drift. The same rock extends far to the south of the road between Loch Borrolan and Allt a' Mhuilinn, for it is visible in small burn-sections about three-quarters of a mile south of the latter locality, where it is again overlapped by the Cambrian quartzites and Lewisian gneiss lying above the Ben More thrust-plane.

Though the material of this extensive plutonic mass in the south of Assynt is generally massive, a distinctly foliated type of borolanite appears to the east of Aultnacallagach Inn in a small stream (Aultivullin) which drains Loch-a-Mheallain and flows southwards into the Allt an Loin Dubh. The same type occurs also on the hill-slope to the east of these localities, and has been traced in the burn-sections on the moor south of Aultivullin as far as the slopes of Cnoc-na-Glas-Choille. The foliation-planes dip towards the east at an angle of 15°, thus coinciding with the general inclination of the post-Cambrian planes of movement.

which occurs in the thrust Eilean Dubh limestone, about half a mile E.N.E. of the village of Elphin.

Special allusion may here be made to the sheet of igneous material which, covering about three square miles of ground near Kinlochailsh and east of Sgonnan Mor in the Oykel valley, is associated with the rocks that overlie the Ben More thrust-plane. The evidence in the field leads to the conclusion that this mass has been brought into conjunction with the displaced Lewisian gneiss and Cambrian quartzites by means of a thrust. Along its eastern margin, for part of the distance, it is in contact with the fucoid-beds and Loch Ailsh marble, and over the remaining portion it is truncated by the Moine-thrust. It consists mainly of a syenite, a typical specimen of which shows under the microscope much micro-perthite and carbonates after a ferro-magnesian mineral, possibly augite and iron-ores. The rock is closely related to the Loch Borrolan mass. In Allt Creag na Fearna, a stream draining the south-east slope of Sgonnan Mor, basic patches which appear in the syenite show the modifications which take place within the mass. To illustrate the gradation of the igneous material, specimens of one of these knots were examined under the microscope, when the core was found to consist of a dark massive rock containing pale-green pyroxene, greenish biotite, and a little colourless alkali felspar. The rock surrounding the core is coarse-grained and massive, and is composed of micro-perthite, oligoclase, green augite, and biotite, with sphene and apatite as accessories. Dr. Teall terms the latter an augite-biotite-syenite, which has affinities with the augite syenites of the Christiania district. It is evident, therefore, that syenites of the type of the Cnoc-na-Sroine mass must have extended far to the east of their present limits, as the Loch Ailsh sheet has been driven westwards with Lewisian gneiss, Torridon Sandstone, and Cambrian strata by the Ben More thrust.

Along its eastern margin, where the igneous mass presents a basic phase, being a hornblendite with pyroxene, merging in places into an augite-biotite-diorite, it comes in contact with the fucoid-beds and dolomite, and greatly affects them. The fucoid-beds become there a brecciated hornfels, and pass into a rock composed of oligoclase, carbonates, biotite, hornblende, and possibly quartz. The overlying dolomite is changed into an ophicalcite, and the isolated patches in the basic intrusion contain green biotite, diopside, and other contact minerals.

The dykes associated with this outbreak of igneous activity in the west of Sutherland and Ross are comparatively rare. Close by the western margin of the Loch Ailsh sheet, in a burn a quarter of a mile north of the top of Sgonnan Mor, and in a crag west of Loch Coire na Meidhe on the west face of that mountain, two examples of orthophyre occur, which Dr. Teall regards as the dyke phase of the syenite magma.

Again, a dyke of the Canisp porphyrite type, showing spherulitic structure, pierces both divisions of the quartzite on the south side of that hill, and has been traced at intervals across the Lewisian gneiss plateau by Lochinver Bridge to the promontory south of Achmelvich Bay.

Of special importance are the dykes of borolanite referred to by Dr. Teall (Chapter XXX.) which traverse the Torridon Sandstone in the Coigach district. The best examples of these appear on the west side of the peninsula at Camas Eilean Ghlais, in Rhu More Coigach, about three-quarters of a mile north of Reiff. The largest of them, which is from 25 to 30 feet wide, may be followed from a point 300 yards east of the house down to the shore of the bay. Its direction is about 10° north of west, and it is apparently shifted by N.N.E. faults. Another of the same type, with a parallel course, occurs about 125 yards to the north, and though only about 15 feet wide sends out three small branches. The felspathic matrix of this intrusion shows marked spherulitic structure.

iii. *Possible Volcanic Vent connected with the Assynt Sills.**

Although, as above stated, all the crystalline igneous rocks of Assynt are of intrusive origin and do not of themselves definitely prove that their intrusion was accompanied by any actual volcanic eruption of material to the surface, their behaviour as sills and dykes affords ground for the belief that they may not improbably have been attended with the opening of one or more volcanic vents. The only evidence of such a possible escape of material to the surface during the epoch of the sills has been detected in the bed of the River Oykell at a point about three miles above Loch Ailsh. The stream when low there exposes the two uppermost sub-divisions of the Cambrian quartzite, together with a small outlier of the overlying fucoid-shales. The quartzites are traversed along their bedding-planes by two sills of hornblendic porphyrite or vogesite resembling those intercalated in the Cambrian rocks near Inchnadamff. All these rocks, together with a portion of the Lewisian gneiss on which they rest, have been brought into their present position upon a minor thrust-plane, and have been truncated above by the great Ben More thrust, which has here carried forward the Lewisian gneiss, together with the overlying unconformable Torridonian and Cambrian strata involved with it. At the exact point of the river-bed just referred to, as shown in the accompanying plan (Fig. 19), drawn approximately to scale, the hard "piped" quartzite is pierced by a mass of breccia 22 yards long by 15 yards wide, which is almost entirely composed of limestone or dolomite fragments belonging chiefly to the Eilean Dubh group. The breccia is arranged in layers of coarser and finer texture, dipping steeply towards the edges of the hole in which the breccia lies. The walls of this cavity or pipe are clean cut and practically vertical. A sill of hornblendic porphyrite lies

* By B. N. Peach.

between the bedding-planes of the quartzite, which here dips towards the north and east at angles of from 15° to 20°. This

Fig. 19.—Ground Plan of possible Volcanic Vent, River Oykell, about three miles above Loch Ailsh.

sill where it reaches the breccia sends tongues into it. The molten material has also risen in places between the breccia and the vertical walls of quartzite that form the edge of the pipe. Moreover, it has flowed in between fragments of the breccia and floated them off, so that they are now found totally enveloped in it. A large mass of the "pipe-rock" has been isolated by the porphyrite, which is often vesicular and slaggy. The limestone-breccia has here been converted into a marble, the instertitial fine-grained material being affected as well as the enclosed blocks of limestone. There has likewise been a production of metamorphic magnesian minerals, indicating that some of the blocks were dolomitic at the time of the igneous intrusion.

As the vosgesite and porphyrite sills have been shown to have been intruded prior to the period of great earth-movements, the materials of the breccia must have fallen into this hole in the pipe-rock from above and from a height of more than 200 feet, because the base of the Eilean Dubh dolomite is more than that distance above the top of the pipe-rock. The formation and infilling of this orifice took place before the intrusion of the sills, and probably long anterior to the time of the great stresses in the terrestrial crust which produced the thrust-planes. The appearances here observable afford plausible ground for believing that this orifice in the quartzite was a true volcanic vent, whence only gases may have escaped, and which was filled up by the descent of fragments from the walls of limestone above.

II. Region to the North of Assynt.*

The sills so well developed in Assynt continue for some distance to the north of that district. In the thrust area between Loch More and Beinn Uidhe (Sheets 107, 108), besides the intrusions in the granulitic schist series, many others have been noted in the Cambrian rocks and the Lewisian gneiss. These may be divided into two classes according as they are older or later than the thrusts. Only two of the observed examples are likely to belong to the younger class. These are two thin dykes of mica-trap which occur in the Cambrian limestone in the valley a little above Loch na Creige Duibhe (north of Glendhu). They are both much decomposed, but not sheared or crushed. Of the older series, many representatives have been detected. None of them occur quite so far north as the mica-traps near Loch na Creige Duibhe. The most northerly example at present known is a dioritic rock (2735), which is doubtless an extension of the Assynt sills. It occurs in the Grudie limestone about a third of a mile slightly west of south of Beinn Lice, on the south side of Loch More. The exposure of it is very small, but the intrusion probably takes the form of a thin sill. In the extensive quartzite area which lies to the west, and which has presumably been pushed forward in the same thrust, no igneous intrusions have been observed.

A thin intrusion probably occurs near the base of the quartzite about half a mile slightly west of south of the Ordnance Station

* By C. T. Clough.

on Beinn a' Bhùtha (north-east of Glendhu), but, as the section was not understood when it was examined, we are unable to speak with confidence about it. A little further north, however, both on the south side of Gleann Dubh (Sheet 107) and near the foot of Loch Strath nan Asinnteach, thin intrusive sills, from one or two up to ten or twelve feet thick, are usually to be observed either at the base of the quartzite or only a few feet above the base, and also other thin sills at higher horizons in the quartzite, as in Assynt. The sill at the base of the quartzite is exposed about three-quarters of a mile slightly east of south of Glendhu, and in various places near the little loch rather more than a mile south-east of Glendhu. Possibly it may continue to the north-east side of Glen Coul, but, as it decomposes more readily than the adjacent rocks, it is not often seen. Sills appear on the same horizon further south—for instance, near the north end of Loch nan Caorach and about 700 yards S.S.W. and 700 yards south of the south end of this loch; but in an intermediate area, in Glencoul, and also near the foot of Loch Strath nan Asinnteach (about two miles east of Glendhu), the intrusive rock has generally found a place not at, but a little distance above, the base of the quartzite.

The other horizons in which sills are most commonly found here are a little below the base and a little below the top of the pipe-rock. In the former position are the sills which appear in several places near the foot of Loch Strath nan Asinnteach, on both sides of Glen Coul, and about half a mile west and 700 yards slightly west of south of the south end of Loch nan Caorach (Sheet 107). On the higher horizon are the sills about a mile and 700 yards south-east of Glendhu, half a mile N.N.W. of the north end of Loch nan Caorach, the east side of Loch nan Caorach, half a mile west and two-thirds of a mile south of the south end of Loch nan Caorach. At the last-mentioned place the sill is sometimes as much as 40 or 50 yards wide, with a high dip. This unusual width does not seem due to repetition by thrusts. Some other sills in the basal quartzite in the same neighbourhood are also unusually wide.

In this district no sills have been noticed within the fucoid-shales. A sill has invaded the serpulite-grit a third of a mile S.S.E. and about half a mile south-east of the south end of Loch nan Caorach. Besides the intrusion already mentioned as occurring in the Grudie limestone near Beinn Lice, sills appear in the same limestone on the east and south-east sides of Loch nan Caorach.

In the unthrust area between Loch Inchard and Loch a' Chàirn Bhàin (Sheets 107 and 113), the only intrusions that seem likely to be of post-Cambrian age are (1) some thin sheets of mica diabase near Rudh' an Tiompain, on the coast south-west of Loch Laxford; (2) three or four north-east-south-west dykes of olivine diabase on the coast near Loch na Claise Iuchairich (two and a half miles south-west of Rhiconich), and a thin sheet of chocolate-coloured porphyrite on the coast about a mile west of

Glendhu. None of these have much resemblance to the intrusions which, in Assynt and elsewhere, are affected by post-Cambrian thrusts.

An intrusion which lies within the Lewisian gneiss on the west side of the quartzite half a mile west of the south end of Loch nan Caorach (Sheet 107) seems to be connected with the sill at the base of the quartzite, and the sill about three-quarters of a mile slightly east of south of Glendhu appears at one place to run off into the gneiss. In the glen south-east of Loch Beag, of Loch Glencoul (Sheet 107), are many intrusions, which, though confined to the gneiss area, present much the same lithological character as the sills in the Cambrian rocks. They have been partly sheared. The best exposures of them may be seen on the south-west side of the glen from about half a mile west to a mile and a half S.S.E. of the head of the loch. They often form rather conspicuous green ledges and recesses in scars. One of them was traced, with an interruption, in a north-westerly direction for about a mile. The others also have generally nearly the same trend, though liable to rather sudden twists. Sometimes two of them unite at a considerable angle. Perhaps for the most part they may be regarded as low-angled sheets. They often cut the gneiss and the Scourie dykes, and even where the strike of the gneiss is not north-west this continues still to be their prevalent direction.

CHAPTER XXX.

POST-CAMBRIAN IGNEOUS ROCKS OF OLDER DATE THAN THE GREAT THRUST-MOVEMENTS OF THE REGION: THEIR PETROGRAPHY.*

The post-Cambrian igneous rocks described in the last chapter have been shown to occur as plutonic masses and as sills or dykes, but without any lavas or effusive types.

i. *Plutonic Masses.*

The principal plutonic mass stretches from the neighbourhood of Ledbeg for about five miles in a south-easterly direction, with an average width of rather less than one mile. Cnoc-na-Sroine (1306 feet) forms the culminating point. This mass is by no means uniform in composition. It includes granite, quartz-syenite, melanite-syenite, nepheline-syenite, and borolanite; while the outlying patches which occur as satellites to the main mass supply additional varieties such as acmite-granite and pyroxenite.

The rock which forms the hill of Cnoc na Sroine is a red granite, remarkably poor in ferro-magnesian or any other dark-coloured constituents. The amount of quartz is variable. Sometimes this mineral is present in considerable quantity, and the rock is then a true granite; at other times it is rare or absent, and the rock becomes a syenite. A typical specimen from the burn behind the inn at Aultnacallagach (3082) is a coarse-grained red granite or quartz-syenite, composed mostly of felspar, but containing also a few blebs of quartz and some insignificant dark specks representing a ferro-magnesian constituent. Under the microscope two felspars are recognisable. The plagioclase occurs in more or less idiomorphic crystals, which are often zoned and always twinned on the albite plan. The twin lamellæ are numerous and very narrow. The second felspar occurs in large irregular plates, and shows moiré-structure under crossed nicols; it is often twinned on the Carlsbad plan, and frequently contains inclusions of idiomorphic plagioclase. Quartz occurs in irregular grains. The ferro-magnesian mineral is represented by minute scales of chlorite.

When the powder of the rock is placed in a diffusion column three well-marked bands are formed, one corresponding to quartz,

* By J. J. H. Teall.

which is present only in small quantity (2.65), another corresponds to albite (2.62), and a third to orthoclase. Although the specific gravity of the plagioclase practically agrees with that of albite, the extinctions on M-flakes are slightly less than those characteristic of this mineral — 15° to 17°, as against 19°. The optical characters of the second felspar agree with orthoclase. Of the two felspars albite is the more abundant.

Another specimen (3090) from Cnoc na Sroine (about six miles south of Inchnadamff) is very similar in general appearance, but contains less quartz. In this rock the two felspars are intimately intergrown, and often take on the character of micro-perthite. Other red rocks from the same mass are true syenites, without quartz, and these sometimes contain pseudomorphs after nepheline as well as accessory melanite (3083). The felspars are either orthoclase or micro-perthite.

The greater portion of the area which is composed of plutonic rocks is occupied by varieties similar to those above described, but on the margins and to the south-east other varieties occur. The most important of these varieties are grey or black in colour, and contain melanite as an essential constituent. On the one-inch map the south-eastern portion of the plutonic area is coloured as borolanite, but this area is by no means uniform in composition. Typical borolanite is best seen in the small burn named Allt a' Mhuilinn on the six-inch map, and in the area to the east of this burn. The burn has no name on the one-inch map, but it may be easily recognised as it crosses the road about one and a quarter mile east of the inn at Aultnacallagach. Between the eastern end of Loch Borrolan and Allt a' Mhuilinn the crags overlooking the road are formed of rocks which contain less melanite than the typical borolanite, and may be appropriately termed melanite-syenite. They are largely composed of grey orthoclase, with variable amounts of green biotite and melanite. Micaceous pseudomorphs, precisely similar to the so-called liebenerite, and presumably after nepheline, are sometimes present. The grains of melanite are sometimes surrounded by an opaque border reminding one of that which commonly surrounds the hornblende in hornblende-andesites. In some cases only a trace of melanite substance remains, and in others none at all. Melanite-syenites are not limited to the area in question. They occur also on the lower slopes of Cnoc na Sroine to the north, and in the Ledmore River between Loch Borrolan and the shepherd's house at Ledmore. Many interesting varieties may be collected from the last-mentioned locality. A specimen from a point 200 yards east of Ledmore Lodge, close to the Ledmore River (9920), is a medium-grained mottled rock in which the light and dark coloured constituents are unequally mixed. The constituents are orthoclase, melanite, green biotite, alteration products after nepheline, sphene, epidote, and apatite. Another specimen from the Ledmore River not far from the above (9923) is a dark-grey, medium-grained melanite-biotite-syenite, verging on typical borolanite. The light-coloured constituents are orthoclase and micro-graphic intergrowths of orthoclase, and the alteration product after nepheline, such as occur in the psuedo-leucites of the borolanite hereafter to be described.

Typical borolanite* is best seen in Allt a' Mhuilinn and in the area to the east. The crags overlooking the road immediately to the east of the burn furnish excellent exposures. The rock is dark in colour and of medium-grain. It contains whitish patches, usually more or less spherical or ellipsoidal in form, but occasionally showing polyhedral boundaries. These patches vary considerably in size. The smallest are only just distinctly visible to the naked eye; the largest measure an inch or more across. Where the rock has been subjected to deformation during or subsequent to consolidation, the white patches take the form of lenticles or streaks.

The dominant constituents of the main mass of the rock are orthoclase and melanite; plagioclase, an alteration product after nepheline, and biotite come next in importance. Apatite, sphene, and iron-ores occur as accessory constituents.

Orthoclase is the principal felspar. Soda-felspar is comparatively rare. It occurs as small grains between large, irregular individuals of orthoclase, as grains in association with similar grains of orthoclase, and also as a constituent of micro-perthite.

Next to orthoclase, melanite is the most important constituent. It is black when viewed macroscopically, and possesses, when fractured, a somewhat resinous lustre. Good crystalline form is absent, as a rule, but perfect little crystals may occasionally be observed. The dominant form is the rhombic dodecahedron (110). The edges of this form are sometimes truncated by those of the icosi-tetrahedron (211), exactly as is the case with the well-known melanite from Frascati. In thin sections the colour of the melanite varies from a pale to a very deep brown. The central portions are sometimes more deeply coloured than the margins, and sometimes the reverse relation may be observed. The borders of the differently tinted portions may correspond to the crystallographic outlines of the individual, thus producing true zonal structure, or they may be irregular. The individuals vary in size from very small grains, only .05 mm. in diameter, to large crystals or irregular masses measuring 1 or 2 mm. across. Iron-ore, sphene, and biotite occur as inclusions, and the mineral is both idiomorphic and allotriomorphic with respect to felspar.

The biotite is black when viewed macroscopically. Cleavage flakes, examined with the microscope, appear dull dark-green by transmitted light and are nearly uniaxial. Thin sections at right-angles to the principal cleavage, when tested for pleochroism, change from dark-green to yellowish-brown. The individuals vary considerably in size, and are generally irregular in form. The larger flakes are often corrugated. Pyroxene, iron-ores, garnet, and occasionally felspar occur as inclusions.

* "On Borolanite—an Igneous Rock intrusive in the Cambrian Limestone of Assynt." By J. Horne and J. J. H. Teall, *Trans. Roy. Soc. Edin.*, vol. xxxvii., Part I. (No. 11), pp. 163–178.

Of the accessory minerals, sphene is the only one that deserves special mention. It occurs in the form of minute (.03 x .07 mm.) spindle-shaped granules, which are found only in the melanite. These granules sometimes occur so abundantly as to leave scarcely any of the isotropic garnet-substance between them in the thin sections. At other times they are entirely absent. If these melanites were isolated and analysed they would in general be found to be highly titaniferous, but this would not prove that titanium was present in the melanite-molecule.

Pyroxene is rare in typical borolanite, but it occurs in the associated rocks, some of which are true augite-syenites. When present it is usually without any very definite crystalline form, but sometimes the individuals are elongated in the direction of the vertical axis and more or less idiomorphic in the prismatic zone. The forms recognisable are (110), (010), and (100). The orthopinacoid (100) is always conspicuous when any trace of form is present. The mineral is green in thin section, but the tint is not uniform, the marginal portions being often more deeply coloured than the central parts. The maximum extinction is about 40°. All the above characters agree with those of the ægirine-augite known to occur in nepheline-bearing rocks.

The white patches already referred to as occurring in the typical borolanite of Allt a' Mhuilinn undoubtedly correspond to the pseudo-leucites described by Derby, Hussak, and J. F. Williams from the phonolites of Brazil and the leucite-syenites of Magnet Cove, Arkansas. Under the microscope these patches are in all cases seen to be aggregates. They are principally composed of orthoclase and an alteration product probably after nepheline. Micrographic intergrowths of orthoclase and the alteration product are not unfrequent.

In the majority of cases the rocks are massive and granitic in structure, but in some instances a well-marked foliation may be observed. In the foliated varieties the white patches have been drawn out into lenticles and streaks, and the structure both of the lenticles and of the matrix is then granulitic.

The rock most nearly allied to borolanite is unquestionably the "leucite-syenite" from the igneous complex of Magnet Cove, Arkansas, described by the late J. F. Williams.* This rock is described by Williams as "a hypidiomorphic granular combination of pseudo-leucite, eleolite, orthoclase, and basic silicates, which presents a more or less perfect granitic structure, and is genetically connected with the eleolite-syenite dike-rocks." The pseudo-leucites are composed mainly of orthoclase and nepheline, as were, in all probability, those of borolanite, but they are more perfect in form. The ground mass of the leucite-syenite consists principally of eleolite, melanite, and orthoclase. A green pyroxene, biotite, and sphene are also present.

* "The Igneous Rocks of Arkansas," *Annual Report of the Geological Survey of Arkansas for 1890*, vol. ii.

Melanite, according to Williams, "is found in varying quantities in the different specimens. In some it is almost entirely wanting, while in others it is very abundant. It is of a rich brown or yellowish-brown colour, decidedly zonal in its structure and isotropic in its optical characters. . . . In some cases more than half the area enclosed within the boundaries of the section consist of melanite material." This description leaves no doubt that these portions of the "leucite-syenite" of Magnet Cove, which, by the way, contains no leucite, are practically identical with the borolanite of Assynt.

Outside the plutonic area of Cnoc na Sroine and its immediate vicinity, the only district in the North-West of Scotland where rocks allied to borolanite are known is in the Coigach district of West Ross-shire, about five miles to the north-west of Achiltibuie and about seventeen miles slightly south of west of Cnoc na Sroine*. Here the late W. Gunn found two vertical dykes of a peculiar rock intrusive in Torridon Sandstone. The rock is of medium grain, brownish-grey, and massive. Lath-shaped cleavage faces of felspar may be seen with the unaided eye, and numerous black specks (melanite) with the assistance of a lens.

Under the microscope the rock is seen to be composed of orthoclase, nepheline and its alteration products, melanite, ægirine, and biotite. The main mass is an aggregate of orthoclase and nepheline or its alteration product. Melanite is scattered through the orthoclase-nepheline aggregate in small idiomorphic crystals, which usually consist of a deeply-coloured nucleus surrounded by a pale external zone. Ægirine occurs in long slender prisms, which are idiomorphic in the prismatic zone.

* A remarkable foliated rock, essentially composed of alkali-felspar, melanite, ægirine, and biotite, occurs as an integral portion of the eastern Highland schists at a point half a mile east-south-east of Derry Lodge, Aberdeen. An analysis by Dr. Pollard gave the following result:—

SiO_2	61·79
TiO_2	·90
Al_2O_3	16·90
Fe_2O_3	3·10
FeO	1·07
MnO	·19
CaO,	2·44
MgO	·90
K_2O	6·96
Na_2O	5·26
P_2O_5	·34
H_2O at 105°	·14
H_2O above 105°	·29
	100·28

This rock has been referred to (*Summary of Progress* for 1901, p. 160) as ægirine-granulite. It is allied in chemical and mineralogical composition to the melanite-syenites of Assynt, and if of the same age, which is of course doubtful, it would prove that the crystalline schists of the eastern Highlands are in part at least of post-Cambrian date.

The rock of the dykes contains less melanite than the typical borolanite of Allt a' Mhuilinn, from which it differs also in containing unaltered nepheline and ægirine. An analysis of this rock by Mr. J. Hort Player is given below side by side with an analysis of the "leucite-syenite" of Magnet Cove:—

	I.	II.
SiO_2	47·8	50·96
Al_2O_3	20·1	19·67
Fe_2O_3	6·7	7·76
FeO	·8	—
MgO	1·1	0·36
CaO	5·4	4·38
Na_2O	5·5	7·96
K_2O	7·1	6·77
H_2O (Ig.)	2·4	1·38
TiO_2	·7	·52
SO_3	·4	—
MnO	·5	tr.
BaO	·8	—
Cl	—	·25
	99·3	100·01

I. Borolanite dyke, Camas Eilean Ghlais.
II. "Leucite-syenite," Magnet Cove. Analysis by Noyes.

The borolanite of the low crag close to the main road and immediately east of Allt a' Mhuilinn is traversed by a coarse-grained pegmatite composed of orthoclase and an alteration porduct, presumably after nepheline. The orthoclase is in thick tables with conspicuous development of the clino-pinacoid, and the individuals often measure an inch or more across. The alteration product is either white or pale-blue. It shows aggregate polarisation, and is decomposed by hydrochloric and sulphuric acids, with the separation of gelatinous silica and the evolution of bubbles. The white substance has been separated and analysed by Dr. Pollard with the following result:—

SiO_2	43·35
Al_2O_3	31·93
Fe_2O_3	·78
CaO	1·53
MgO	·28
K_2O	6.16
Na_2O	8·03
Li_2O	·15
CO_2	·57
SO_3	1·67
H_2O (105)	·38
H_2O (above 105°)	5·47
	100·30

The state of oxidation of the iron was not determined. A trace of manganese is present. The principal result of the alteration of the nepheline has been the removal of a considerable amount of soda and the introduction of water. The presence of sulphuric acid is remarkable, and suggests the presence in the original rock of a mineral of the Hauyn group. Chlorine was looked for but not found.

The presence of this pegmatite in the borolanite is of considerable interest in connection with the discovery of a boulder of true nepheline-syenite-pegmatite by Mr. Hinxman on the east slopes of Coul More, about five miles west of Cnoc na Sroine, and, therefore, in the direction of the movement of the ice of the glacial period. The boulder measured 9 x 5 x 4 inches. Its component minerals are orthoclase, nepheline, and ægirine. The individuals of orthoclase are of a dull, dark, purplish-grey colour, similar to the orthoclase of the pegmatite vein above referred to, but larger, as the cleavage faces sometimes measure three or four inches across. Nepheline occurs in large masses measuring one or two inches in diameter. Neither of these two minerals possesses any decided superiority over the other so far as idiomorphism is concerned. Ægirine is present in the form of long slender prisms, sometimes measuring two or three inches in length by a quarter of an inch in breadth. It is sharply idiomorphic in the prismatic zone with development of the orthopinacoids and prismatic faces, and it pierces alike the orthoclase and the nepheline. In view of what is now known, there can be no doubt that this boulder was derived from the plutonic complex of Cnoc na Sroine; otherwise it might well have been supposed to have travelled from the Christiania district.

From the description already given of the rocks of the complex, it appears that, although an alteration product after nepheline is fairly common in the melanite-syenites and borolanites which form the eastern portion of the mass, fresh nepheline is generally absent*. Great interest, therefore, attaches to the occurrence of comparatively unaltered nepheline-syenite on the north side of Cnoc na Sroine, at the base of the slopes, and on the south side of the Ledbeg River. There are no large continuous exposures of this rock. It occurs in bosses protruding through the peat half a mile south-east of Loyne shepherd's house.

The best specimens of nepheline-syenite may be obtained from coarse-grained bands measuring only one or two inches in width, and traversing in a more or less horizontal direction a finer grained nepheline-melanite-syenite or borolanite. The bands do not appear to be separate intrusions, but merely coarse-grained portions in which there are fewer dark-coloured constituents (melanite and biotite). Taking a specimen (3095) as a type, the weathered surface is seen to be rough, owing to the more rapid weathering of the nepheline, which has a dull-green, waxy appearance. The alkali-felspar is present in flat tables with conspicuous development of the clino-pinacoid, and the crystals are often twinned on the Carlsbad plan. Under the microscope the rock is seen to be composed of nepheline and alkali-felspar,

* Mr. Coomaraswamy found a specimen containing fresh nepheline near the waterfall in Allt-a-Mhullin.

in approximately equal proportions, with a greenish biotite and melanite as accessories. Both felspar and nepheline are present as large individuals, measuring half an inch or more across.

The principal varieties of the main plutonic mass and its satellites have now been described, and it remains only to notice one or two exceptional types.

A coarse-grained pegmatitic variety of acmite-granite may be observed above the bridge over the Ledbeg River near Ledmore Lodge. The constituents are quartz, microcline, albite or oligoclase-albite, and acmite, with pyrite as an accessory. Acmite occurs in long slender prisms. The pleochroism is faint and of the following type:—X, brown; Y, yellow; and Z, brownish-yellow. Close to the above is another striking rock composed of pink orthoclase and a dull green substance, which is probably a pseudomorph after nepheline. The individuals of orthoclase often measure an inch across. Under the microscope the pseudomorphs are seen to be confused aggregates of minute mica-scales, closely resembling the so-called liebenerite from the well-known liebenerite-porphyry of the Fleimser Thal in the Tyrol.

About one-third of a mile S.S.W. of Ledmore, in a small burn which runs into the Ledmore River, there occurs a small exposure of melanite-pyroxenite. It is a coarse-grained dark rock, mainly composed of green pyroxene, biotite, melanite, black iron-ores, and pyrite. This is the most basic phase of the borolanite magma known (specific gravity, 3.45-3.56).

A brief summary of the results of the petrographical examination of the plutonic complex and its satellites will now be given. The principal constituents of the different varieties of rock may be classed as follows:—

Colourless.	*Coloured.*
Quartz.	Melanite.
Orthoclase.	Biotite.
Microcline.	Ægirine-augite.
Albite or oligoclase-albite.	Ægirine.
Nepheline.	

The red rocks of Cnoc na Sroine and the pegmatite with pseudomorphs after nepheline are almost entirely free from coloured constituents, whereas the pyroxenite is almost entirely composed of them. Between these two extremes there is a regular gradation when the whole area is taken into consideration, and the most striking differences are seen to be due to a variation in the relative proportions of the coloured and colourless constituents.

Special interest attaches to a comparison of the colourless constituents found in the different kinds of rock. In the quartzose rocks no trace of the existence of nepheline is ever found: nearly the whole of the soda is present in albite or oligoclase-albite. In the quartz-less rocks nepheline or its alteration product is often present, either with or without a soda-felspar. As the amount of nepheline or its alteration product increases, the amount of soda-felspar diminishes, and finally, in the borolanite and nepheline-syenite-pegmatite, orthoclase is the only felspar present. These facts of paragenesis are strictly in accordance with what might be anticipated from the composition of the minerals. In albite the ratio of Na_2O : Al_2O_3 : SiO_2 is 1:1:6, in nepheline it is 1:1:2. When silica is in excess, albite or oligoclase-albite is formed to the exclusion of nepheline. When it is less than that required for the ratio 1:1:6, but greater than that required for the ratio 1:1:2, albite and nepheline may coexist; when it is not greater than that required for the ratio 1:1:2, nepheline alone is formed.

The facts observed are in complete agreement with the principles laid down by Professor Iddings in his paper on the "Chemical and Mineral Relationships in Igneous Rocks."*

In view of the frequent occurrence of anorthoclase in rocks which are more or less allied to those under consideration, it has been looked for, but no evidence of its existence has been found. The potash-felspar appears to be in all cases orthoclase or microcline; at the same time, it should be noted that micro-perthite is not uncommon.

The orthoclase and nepheline of the boulder of nepheline-syenite-pegmatite found on the slopes of Coul More have been isolated and analysed by Dr. Pollard:—

	Orthoclase.	*Nepheline.*
SiO_2	63·84	44·37
Al_2O_3	18·87	32·00
Fe_2O_3	·68	1·53
CaO	·18	·47
K_2O	14·76	6·72
Na_2O	1·23	14·00
H_2O 105°	·30	·11
H_2O above 105°		·87
	99·86	100·57
Sp. Gr.	2·556–2·510	2·60–2·68

The one mineral which is present in all the rocks of the district is orthoclase. It is found in the most acid granites, and is not entirely absent from the most basic pyroxenite. Between the granite and the pyroxenite are many intermediate varieties, which may be conveniently designated by such terms as syenite, nepheline-syenite, melanite-syenite, melanite-biotite-syenite, augite-syenite, and borolanite. The basic rocks occur on the margins of the main mass and in the outlying satellites.

ii. *Sills and Dykes.*

The phase of minor intrusions is represented by innumerable sills and a few dykes. Their distribution is well shown in the

* *Journal of Geology*, 1898, p. 219.

one-inch Sheets 101 and 107, and Inchnadamff forms a good centre from which they may be examined. On the one-inch maps the sills and dykes are represented as felsite and diorite; but for purposes of description it is convenient to recognise three main groups—felsites, porphyrites, and vogesites or spessartites (diorites on the map).

FELSITES.—The most acid rocks are usually pink, more rarely green, in colour and felsitic in texture. Sometimes phenocrysts of alkali-felspar are present, sometimes absent. Quartz is not present in porphyritic crystals, although the analyses show a considerable excess of silica. Ferro-magnesian minerals form an insignificant portion of the mass, and when recognisable are usually represented by ægirine.

Ægirine-felsites are well represented by a sill or dyke traversing the quartzite of the north shoulder of Cnoc an Droighinn, about a mile north-east of Inchnadamff Hotel, in a north-east and south-west direction. The average breadth of the exposure is about 30 or 40 feet. The main mass of the intrusion is a normal pink felsite, but on the north-west side the rock assumes a green colour, and in this variety minute needles of grass-green ægirine may be recognised with a lens.*

Under the microscope the green variety (2324) is seen to be composed of polysynthetic aggregates, representing original porphyritic alkali-felspars, streaks of micro-crystalline quartz, and a crypto- or micro-crystalline felspathic matrix, crowded with acicular microlites of ægirine. Similar microlites occur in the polysynthetic aggregates, just as they do in Professor Brögger's typical Grorudite, but they are far less numerous than in the matrix, where they are often so thickly crowded together as to form a felt-like mass. The larger microlites are green, but the smaller ones are colourless; both show the characteristic optical properties of ægirine when isolated from the matrix. This rock was analysed by Dr. Pollard with the following result:—

SiO_2	75·20	1·2450
TiO_2	·12	·0015
Al_2O_3	12·65	·1238
Fe_2O_3	1·53	·0095
FeO	·28	·0039
MnO	·10	·0014
CaO	·60	·0107
MgO	·26	·0064
K_2O	4·14	·0439
Na_2O	5·67	·0913
H_2O (105°) } H_2O (above 105°) }	·12	·0066
	100·67	

* In a paper on "Nepheline-syenite and its Associates in the North-West of Scotland" (*Geol. Mag.*, 1900, pp. 385–392), the locality of this green felsite is given as Poll an Droighinn. This is a mistake. It is not exposed in the burn but on the hill, Cnoc an Droighinn, to the west of the burn.

From these figures we get the following composition of the rock*:—

$K_2 Al_2 Si_6 O_{16}$ - - -	24·54
$Na_2 Al_2 Si_6 O_{16}$ - - -	42·08
$Na_2 Fe_2 Si_4 O_{12}$ - - -	4·41
SiO_2 - - - - -	28·04
	99·07

The ratio of ortholcase to albite is therefore 1 : 1·82.

Another specimen of acid felsite from a burn a quarter of a mile north of the top of Sgonnan More (8370) consists of numerous phenocrysts of pink felspar, usually giving rectangular sections about a quarter of an inch across, embedded in a compact light-grey felsitic matrix. Under the microscope the phenocrysts are seen to consist of intergrowths of albite and orthoclase similar to those often present in the plutonic mass of Cnoc na Sroine. The ground mass is a micro- or crypto-crystalline aggregate of alkali-felspar and quartz, together with a few minute ragged prisms of ægirine.

The porphyritic felspars and matrix were separated and analysed by Dr. Pollard:—

	Porphyritic Felspar.	Matrix.
SiO_2 - - -	66·73	74·44
Al_2O_3 - - -	19·05	14·72
Fe_2O_3 - -	·86	1·17
FeO - - -		·17
CaO - - -	trace.	trace.
K_2O - - -	6·69	3·99
Na_2O - - -	6·59	5·82
H_2O (185°) -	·17	·06
H_2O (above 105°)	·20	·26
	100·29	100·63
Orthoclase - -	37·63	23·64
Albite - -	56·41	49·36
Silica - -	—	25·15
	96·04	98·15

The ratio of orthoclase to albite is therefore:—

Porphyritic felspars - - -	1 : 1·51
Matrix - - - - -	1 : 2·21

The felspars are thus seen to be intergrowths of albite and orthoclase having the composition of Professor Brögger's crypto-perthite.†

Porphyrites.—The most striking rock belonging to this group is the so-called Canisp porphyry. This is a handsome rock

* Leaving unaccounted for TiO_2 ·12, FeO ·28, MnO ·10, MgO ·26, Na_2O ·12, CaO ·60, H_2O ·12.

† *Zeit. f. Kryst*, 1890, p. 529.

composed of large tabular crystals of oligoclase-albite, measuring half an inch or more in their largest diameter, embedded in a red ground-mass. Brick-red crystals of orthoclase are sometimes present. Under the microscope ægirine-augite and biotite may be recognised as minerals of primary consolidation. The ground-mass is a micro-crystalline aggregate of quartz and turbid felspar. The porphyritic felspars from this rock were analysed by Dr. Heddle, and his analyses show that the orthoclase contains but little soda (1.69 per cent.) and the plagioclase but little potash (1.13 per cent.). The plagioclase corresponds to $Ab_9\ An_1$ and, like that of the more acid rocks belonging to the Cnoc na Sroine complex, is closely allied to albite.

The other members of the porphyrite group all contain hornblende, and in this respect are allied to the vogesites and spessartites of Professor Rosenbusch. They occur abundantly in the Assynt district, and typical examples may be obtained at Loch nan Cuaran, at the head of Allt Pol na Droighinn (three miles north-east of Inchnadamff). The most usual type (9934) consists of numerous small phenocrysts of oligoclase, rarely measuring more than a quarter of an inch across, and still smaller phenocrysts of hornblende, embedded in a dark-grey matrix. The phenocrysts of oligoclase may be either white or red, and they form about one-third of the entire mass of the rock; under the microscope they sometimes show zonal structure, but the successive zones do not differ markedly in optical characters, and the average composition, as proved by specific gravity, is that of oligoclase. The crystals of hornblende are sharply idiomorphic and green in colour. The secondary minerals arising from the alteration of hornblende are epidote and chlorite. The felspars not unfrequently contain numerous minute scales of secondary mica. The ground-mass is a micro-crystalline aggregate of quartz and felspar.

The following analysis of one of these oligoclase-hornblende porphyrites, which is intrusive in quartzite at the base of Beinn an Fhurain, has already been published* :—

SiO_2	63·41
Al_2O_3	16·92
Fe_2O_3	2·67
FeO	2·96
CaO	4·32
MgO	2·08
Na_2O	5·18
K_2O	2·36
Ig.	·64
	100·54

Special interest attaches to the above type of porphyrite from the fact that it occurs in intimate association with Moine-schists on the shore of Loch Broom, at Lech Melm Wood, near Ulla-

* "Notes on some Hornblende-bearing Rocks from Inchnadampff." J. J. H. Teall, *Geol. Mag.*, 1886, p. 346.

pool. As many as a dozen bands of more or less foliated rock may here be seen alternating with dark-coloured platy mica-schist of typical Moine character. The bands vary from a foot to an inch in thickness. The phenocrysts of plagioclase stand out prominently on the weathered surfaces, and, in the markedly foliated varieties, give the rock somewhat the appearance of a fine-grained "augen gneiss." The phenocrysts of oligoclase are precisely similar to those of the normal porphyrite, but the matrix is different. It is a foliated aggregate of alkali-felspar, quartz, epidote, and biotite. The igneous and the sedimentary rocks have been simultaneously affected by powerful movements, and possess a common foliation.

Vogesites and Spessartites.—The dark basic sills which are so common in the dolomites of the Assynt district were originally termed diorites, and have been so mapped. They consist essentially of idiomorphic green hornblende and two felspars. A pale-coloured pyroxene is often present, and is sometimes as abundant as the hornblende. Apatite and magnetite occur as accessories; carbonates, chlorite, and epidote as secondary constituents. Orthoclase and plagioclase are both present, but the condition of the rocks is such as to make it extremely difficult to determine which of the two predominates, and, therefore, to separate the vogesites from the spessartites in accordance with the classification proposed by Professor Rosenbusch for rocks of this type.

Since this description of borolanite and its associates was written, an important paper by Dr. J. Shand—"Ueber Borolanit und die Gesteine des Cnoc na-Sroine Massivs in Nord-Schottland"—has appeared. (*Neues Jahr. f. Min., etc.*, Beilage Band xxii., 1906, p. 413.) In this paper the author classifies the rocks as follows:—Quartz-syenite, quartz-free syenite and pegmatite, nepheline-syenite, nepheline-augite-pegmatite, borolanite and leucite-borolanite, nepheline-borolanite, augite-sodalite-syenite, aegirine-syenite, aegirine-felsite and pyroxenite.

He describes the rocks in detail, and records the presence of sodalite in quartz-free syenite, nepheline-augite-pegmatite, borolanite and leucite-borolanite. He has carefully studied the peculiar intergrowths of orthoclase and a second mineral to which reference has been made, and has arrived at the conclusion that the second mineral was originally sodalite, not nepheline, as suggested above.

There are many other points of interest in the paper, but these are the most important in which the author adds to or differs from the statements made in this chapter.

CHAPTER XXXI.

CONTACT METAMORPHISM OF THE CAMBRIAN DOLOMITES AND LIMESTONES.*

The rocks of the Cambrian Calcareous series have undergone important alterations, both in Assynt and in Skye, as a result of the intrusion of igneous rocks. In Assynt the effects are due to the granite, quartz-syenite, augite-syenite, nepheline-syenite, and borolanite, which together make up the plutonic complex of Cnoc na Sroine; in Skye they are due to igneous rocks of Tertiary age. The following account of this metamorphism has reference mainly to the phenomena seen in the Assynt district, but, as those of Skye are similar, some reference to that locality will also be made.

The marbles of Assynt have attracted the attention of many previous writers on the geology of the district. The fullest description of them which has hitherto appeared is that by Dr. Heddle in his papers on the Geognosy and Mineralogy of Scotland†, to which reference has been made in Chapter XXIX. This author gave particulars as to their distribution, structure, and composition, and arrived at the conclusion that the marble is a metamorphosed dolomite—a conclusion which the detailed mapping of the ground by the Geological Survey has fully confirmed. He also observed that "the localities where the marble occurs lie round, and nowhere at much greater distance than a mile from, the quartz-porphyry of Cnoc na Sroine or from the spurs of that hill"; but he does not draw the obvious conclusion that the marbles are the direct result of the action of this rock upon the dolomite. In his second paper he gave a detailed description of a peculiar variety of the marble showing structures which were identified by Dr. Carpenter as being similar to those of the Canadian specimens of eozoon. Calculating the lime and magnesia soluble in "moderately strong acid with gentle heat" as carbonates, the matrix of the rock showing the structure in question was found to contain 46.307 of carbonate of lime and 37.632 of carbonate of magnesia. The insoluble residue amounted to 14.408 per cent., and consisted, according to Dr. Heddle, of "rounded crystals of malacolite, with small quantities of serpentine, quartz, margarodite, and

* By J. J. H. Teall.

† *Mineralog. Mag.*, vol. iv., p. 242, and vol. v., p. 271.

magnetite." In view of the facts to be stated subsequently, it is highly probable that the rounded crystals were in part at least forsterite, not malacolite, and the presence of quartz is somewhat doubtful; but the analysis clearly proves that the material contained a considerable amount of magnesia in the form of carbonate, no doubt present as dolomite. Another specimen analysed by Dr. Heddle gave 55.562 per cent. of carbonate of lime and 39.942 per cent. of carbonate of magnesia, along with 4.238 per cent. of insoluble residue, said to consist entirely of granules of malacolite. An analysis of the marble of Ledbeg by Dr. Anderson gave the following result:—

Carbonate of Lime	91·32
Carbonate of Magnesia	4·74
Alumina, Ferric Oxide, &c.	·2
Silica	4·34
	100·60

It will be noted that Dr. Anderson's specimen contained much more carbonate of lime than the two specimens analysed by Dr. Heddle. In his description of the microscopic sections of the rock showing eozoonal structure, Dr. Heddle records the presence of a fibrous mineral which he somewhat doubtfully refers to as wollastonite, and a partially serpentinised ovoidal mineral which he regards as malacolite. The fibrous mineral was probably brucite and the ovoidal mineral forsterite. The results of the examination of the Survey specimens will now be given.

Minerals of the Altered Rocks.—The altered rocks of Assynt which have been invaded by the plutonic complex, described in the foregoing chapter, contain the following minerals:—Calcite, dolomite, brucite, diopside, forsterite, serpentine, mica, and tremolite. The same minerals occur in the corresponding rocks from Skye, together with a violet spinel. Mr. Harker has also observed idocrase and garnet in the immediate neighbourhood of the Tertiary igneous rocks of the Broadford district.

In the microscopic examination of the altered rocks it has been found impossible to distinguish between Calcite and Dolomite in any other way than by the Lemberg staining test. This, however, is decisive and therefore invaluable. Both minerals are usually present, but in very different proportions in different cases.

Next to carbonates, Brucite is perhaps the most common mineral. It is present in several specimens both from Assynt and Skye. The specimen selected for the determination of this mineral came from the Ledbeg River (9208), about half a mile E.S.E. of Loyne shepherd's house. The rock is of medium grain, nearly white, and effervesces freely with dilute acid. The weathered surface is extremely rough, owing to the projection of small crystals of dolomite. The fractured surface when examined with a lens discloses the presence of light-coloured more or less rounded grains (1 to 2 mm.) in a mass of white carbonate. Under the microscope these rounded grains are seen to consist of fibrous or scaly aggregates, which often show a kind of plumose arrangement, and give, between crossed-nicols, the colours of the first order. This substance has all the characters of a pseudomorph. The larger grains above referred to are generally without form, but smaller grains (.1 to .2 mm.), occurring in the same slide and evidently composed of the same substance, give square, triangular, and hexagonal outlines such as are characteristic of octahedra.

An attempt to isolate the mineral from the carbonates by the action of dilute acid failed, for it was dissolved as readily as dolomite, and almost, if not quite, as readily as calcite. A perforated cover glass placed over the slide, so as to expose a portion of one of the larger grains, allows the action of dilute acid on the substance to be studied. Sometimes it fades away without effervesence, and sometimes one or two bubbles make their appearance when the acid is first applied; but there is no continuous effervescence during the solution of the mineral. The solution gives an abundant precipitate of the characteristic ammonio-magnesic phosphate when tested on a slide for magnesia in the manner recommended by Behrens. The mineral may be isolated in a state of tolerable purity by the aid of any heavy solution which does not act on carbonates. This has been done by Dr. Pollard. It floats in a solution of bromoform of sp. gr. 2.41. The grains, when treated on a slide with dilute hydrochloric acid, behave in the same manner as those in the slide. There is almost always a slight effervesence at first, but afterwards the mineral fades quietly away. Sometimes the effervesence can be distinctly traced to specks of calcite included in the mineral. As a similar mineral occurring in the predazzite of the Tyrol has been referred to hydro-magnesite (O. Lenecek: Ueber Predazzit und Pencatit., *Min. Mitth.* XII., 1891, 429-456), it was desirable to remove all doubt as to its nature. The substance (.2388g.) isolated in the manner above described was accordingly analysed by Dr. Pollard with the following results:—

SiO_2	·4
Al_2O_3, Fe_2O_3	1·4
MgO	60·0
CaO	·8
Loss on Ig.	31·2
	99·8

Calculating the loss as water, this gives a ratio of $MgO:H_2O$ as 1:1.06, and leaves no doubt that the bulk of the substance analysed was brucite. The amount of carbonic acid present was not estimated, but qualitative experiments proved that it must have been very slight. Brucite occurs in several specimens from Ledbeg River, and also from Kilchrist in Skye. The specimens from the latter locality bear the most striking resemblance in general appearance and microscopic character to specimens of the typical predazzite from the Tyrol.

In the paper by Lenecek above referred to, the so-called hydromagnesite is regarded as a pseudomorph after periclase; no unaltered periclase has been found in the metamorphosed dolomites of Assynt and Skye, but the octahedral form of the smaller grains in the rock from the Ledbeg River is unmistakeable, and the brucite is therefore very probably a pseudomorph after this mineral.

The normal Pyroxene of the altered rocks is a colourless Diopside. It is often aggregated in patches, which suggest that it has been formed at the expense of the cherts occasionally found in the dolomite (6738, Skye). The individual grains are allotriomorphic with respect to each other, but often more or less idiomorphic with respect to the carbonate. The prismatic faces are then well developed, and the clino-pinacoid has also been identified. The characteristic cleavages are strongly marked, and repeated twinning has been observed. It is worthy of note that the normal diopside (CaO, MgO, 2 SiO_2) can be formed from dolomite (CaO, MgO 2 CO_2) by the substitution of silica for carbon dioxide. The presence of quartz or chert in the original rock will therefore supply the necessary constituents for the formation of diopside in a dolomite. Moreover, the formation of diopside in a dolomite does not involve dedolomitisation.

Some rocks of exceptional character and apparently of compound origin occur in the Ledbeg River about 400 or 500 yards north-east of Ledbeg (four and a half miles south of Inchnadamff). The calcareous members of the series from this locality (9203 to 9205) contain two varieties of pyroxene; the one a colourless diopside similar to that already referred to, the other a green mineral identical with the ægirine-augite of the augite-syenites. The green pyroxene sometimes forms a distinct and sharply-defined border to the colourless variety (9205). As both field and microscopic evidence suggest interaction between the igneous and sedimentary rocks, the green pyroxene was isolated from its matrix of calcite (9203) and analysed by Dr. Pollard with the following result:—

SiO_2	53·58	·8871
TiO_2	tr.	—
Al_2O_3	1·32	·0129
Fe_2O_3	9·46	·0591
FeO	3·36	·0467
MnO	·31	·0043
CaO	16·82	·3003
MgO	11·67	·2891
K_2O	·20	·0021
Na_2O	3·31	·0533
LiO_2	tr.	—
Ignition	·73	·0405
	100·76	

Sp. gr. above 3·28; ·5032gr. taken for main analysis, ·5g. for alkalies, ·329g. for FeO. Ratio of CaO : MgO—1·04 : 1.

Assuming the following molecules to be present, we have:—

$(NaK)_4\ Fe_2\ Si_4\ O_{12}$	25·76
$Fe\ Fe_2\ Si_4\ O_{12}$	1·76
$Fe\ Al_2\ Si\ O_6$	3·03
$Ca\ Mg\ Si_2\ O_6$	62·73
$Ca\ Mn\ Fe\ SiO_3$	5·99
$Si\ O_2$	·76
$H_2\ O$ (Ig.)	·73
	100·76

This analysis reveals the presence of over 25 per cent. of the characteristic ægirine-molecule, and leaves no doubt that material has passed from the igneous to the metamorphic rock. But, although there has undoubtedly been some interchange of material such as that emphasised by Mr. Johnston Lavis, this interchange, so far as the rocks under consideration are concerned, appears to be limited to the immediate neighbourhood of the junction.

Forsterite and Serpentine derived from this mineral are both common in the altered dolomites of Skye and Assynt, but there is a doubt as to whether all the serpentine has been so formed. In the specimens from Assynt forsterite always occurs in ovoidal grains, which often suggest the form of olivine, but never possess sharp angles. The mineral is quite colourless in thin sections, and frequently shows the characteristic alteration to serpentine along irregular cracks. It was isolated from a rock occurring on the borders of the Cnoc na Sroine mass (3099), and analysed by Dr. Pollard with the following result:—

SiO_2	42·2
Al_2O_3	·8
Fe_2O_3	·5
CaO	·3
MgO	57·0
Ignition	·3
	101·1

Ratio of $MgO : SiO_2 = 2{\cdot}02 : 1$.

It is important to note that the formation of forsterite in a dolomite must, if the bases be retained, be accompanied by the development of calcite. The forsterite in question was embedded in a matrix of calcite. In the above analysis the state of oxidation of the small amount of iron present was not determined, and it is therefore quoted as $Fe_2\ O_3$. An exceptional variety of forsterite occurs in a rock about half a mile west by north of the outlet of Loch Lonachan, south of Broadford, in Skye (6743). The mineral is here developed as thin tables bounded by planes, often meeting in sharp angles. The large flat planes are at right angles to the positive bisectrix, and correspond, therefore, to the macro-pinacoid, on the assumption that the optic orientation is the same as that of normal forsterite. The plates measure from 1 to 3 mms. across, and are somewhat elongated in the direction of the vertical axis, but not markedly so. Their thickness is only about .1 mm. They are much broken up by cracks, and readily disintegrate on the application of the slightest pressure. In addition to the macro-pinacoid (100), which is the dominant form, the basal plane (001), the brachydome (021), and the prism (110) probably occur, but have not been identified with absolute certainty.

As this habit is so different from that of the forsterite usually found in altered rocks from Assynt, Skye, Vesuvius, and elsewhere, the mineral was isolated and analysed by Dr. Pollard:—

SiO_2 - - - - - -	42·6
Al_2O_3 - - - - - -	1·2
Fe_2O_3 - - - - - -	1·2
CaO - - - - - -	·6
MgO - - - - - -	51·2
Ignition - - - - -	3·1
	99·9

The total iron is given as Fe_2O_3, but the state of oxidation was not determined. The ratio $MgO : SiO_2 = 1{\cdot}8 : 1$. Fluorine was looked for but not found.

The Serpentine (9211) is greenish-yellow in colour, and, like the forsterite from which it is in most, if not in all, cases derived, is invariably associated with calcite. In the course of the examination of these rocks a doubt arose as to whether some of the serpentine may not have originated from diopside. A rock from Skye (6783) in which this appeared to be possible, and which contained cores of the parent mineral, was accordingly selected for chemical examination. The comparatively unaltered substance was found by Dr. Pollard to possess the following composition:—

SiO_2 - - - - - -	41·5
Al_2O_3 - - - - - -	·9
Fe_2O_3 - - - - - -	1·4
CaO - - - - - -	·3
MgO - - - - - -	55·6
Ignition - - - - -	1·2
	100·9

Ratio of $MgO : SiO_2 = 2 : 1$.

The other minerals do not call for detailed description. Mica when present is in the form of light-coloured, silvery scales, and is uniaxial. It is rare, and has been noticed only in one or two specimens. Tremolite is also comparatively rare. It occurs as slender prisms associated with calcite.

Petrographical Characters of the Altered Rocks.—The minerals above mentioned are mixed in very different proportions in the different rocks. Those in which brucite occurs are of special interest, because they belong to a type hitherto unrecognised in the British Isles, though long known as predazzite, from the neighbourhood of Predazzo in the Tyrol. A typical specimen of this rock from the Ledbeg River (9208) is a medium-grained, nearly white rock composed of brucite, calcite, and dolomite. The brucite aggregates vary in size from about .1 to above 1 mm. in diameter. The larger grains are mostly rounded in outline, but the smaller ones often give square, triangular, and hexagonal sections, which strongly suggest the conclusion that the material is a pseudomorph after periclase. The carbonates occur as irregular individuals of a somewhat larger size than the brucite. They consist of calcite and dolomite in about equal proportions. Another specimen, also from the Ledbeg River (3096), is a dark-grey crystalline rock composed of calcite, dolomite (scarce), brucite, and a few grains of serpentine probably after forsterite.

The corresponding rocks from Skye occur at Kilchrist. They are very fine-grained or compact, and are sometimes flecked with black patches. The compact white or cream-coloured varieties exactly resemble specimens of predazzite from the Tyrol in the Museum of Practical Geology. The constituents are the same as in the rocks from Assynt, the principal differences being due to a fine-grained texture, and the occasional presence of unaltered forsterite. The specimens come from the upper quarry, Kilchrist (6801 and 6802); from a point 200 yards south-east by east of this quarry (7084); from a quarry close to the south angle of the glebe-fence, Kilchrist (7082); and from a point 500 yards W.S.W. of Kilbride (7083).

Rocks mainly composed of calcite and forsterite, with a varying admixture of dolomite, sometimes with none at all, occur both in Assynt and Skye. A specimen (3099) from the former district is a fine-grained, nearly white rock composed of calcite and forsterite in about equal proportions. The forsterite occurs in colourless, more or less rounded grains, which vary in size from about .2 up to 1 mm. in diameter. The calcite occurs in large ophitic plates, and forms the matrix in which the grains of forsterite are embedded. The forsterite of this specimen has been isolated and analysed. The slight loss on ignition (3 per cent.) shows that but little change to serpentine has taken place, a fact fully supported by the microscopic evidence.

Another type of rock composed of calcite, dolomite, and forsterite is represented by a specimen (6743) collected by Mr. Clough, from a point half a mile west by north of the outlet of Loch Lonachan in Skye. In this case the forsterite occurs in the form of thin tables. The matrix is a crystalline-granular aggregate of carbonates, the individuals of which measure from .1 to .2 mm. in diameter. Calcite and dolomite cannot be distinguished from each other in the ordinary microscopic slide, but after staining they are easily separable. It is then found that the calcite grains are grouped around the forsterite-crystals, while the dolomite occupies the interspaces. This relation can be explained if we assume that the original rock was a dolomite containing some silica, either in the form of chert or quartz, and that the forsterite has been formed by taking the magnesia from the dolomite in its immediate neighbourhood.

The specimens containing calcite and forsterite are connected with the ophicalcites by transitional forms. If the specimens from Skye are considered along with those from Assynt, a fairly continuous series can be made out among the combined examples. The specimen from the base of Cnoc na Sroine (3099), already referred to, is a good example of a rock essentially composed of calcite and forsterite; a second, from the shore north of Camas Malag, Loch Slapin, in Skye, shows forsterite in various stages of alteration to serpentine; a third, from a small quarry south-east of Kilchrist (6804), is composed of alternating layers of white calcite and greenish-yellow serpentine with cores of unaltered forsterite; and a fourth, from near the Loch Ailsh road, east of Aultnagallagach, Assynt (9211), is a true ophicalcite composed of calcite and yellowish-green serpentine, which shows by its form and microscopic structure that it has been derived from forsterite.

A specimen from a quarter of a mile south-east of Suardal Farm, Skye (6788), illustrates another type of rock. It consists of more or less rounded lumps of white diopside, measuring one or two inches in diameter, embedded in a dark-bluish crystalline matrix. The forms of the nodular patches suggest that they are due to the presence of chert in the original dolomite. Under the microscope the constituents are seen to be diopside, dolomite, calcite, forsterite, and tremolite. The diopside of the nodules is idiomorphic with respect to dolomite, which is seen to be directly moulded upon it. The matrix is mainly composed of dolomite, but contains also calcite, forsterite, and tremolite; moreover, the calcite is directly associated either with tremolite or forsterite. Thus the patches of calcite either surround crystals of forsterite or are penetrated by prisms of tremolite. This association of minerals accords with the view that the metamorphism has been accompanied by dedolomitisation, for the development of forsterite (2 MgO, SiO_2) and tremolite (CaO, 3 MgO, 4 SiO_2) in a siliceous dolomite must be accompanied by the formation of calcite, if the alteration is brought about by simple interchange of constituents with the loss of carbonic acid.

In addition to the types above described, the series of specimens from Assynt and Skye includes rocks in which the principal constituents (calcite, dolomite, brucite, forsterite, tremolite, and diopside) are mixed in different proportions. Some are banded, so that the relative proportions of the different minerals may vary in a hand specimen or even in a microscopic slide.

Some exceptional rocks occur in the immediate neighbourhood of the contact with borolanite and augite-syenite in the Ledbeg River (9203-9207). In addition to colourless diopside, mica and carbonates, mainly calcite, these rocks contain a green ægirine-augite identical with that occurring in the augite-syenite. The green pyroxene is aggregated in lumps and patches in a matrix of calcite either by itself (9203) or in association with the round colourless diopside (9205). In the latter case it forms a border to the colourless variety. One specimen of the series deserves special attention (9206). It is a mottled dark-green and white rock composed of calcite, orthoclase, and an ægirine-augite. One portion of the specimen consists of ægirine-augite and orthoclase, the other of the same augite in a matrix of calcite. There is absolutely no difference in form, size, or colour between the pyroxene associated with the calcite and that associated with the orthoclase. The only way in which such a rock can have been formed is by a most intimate blending of the igneous and sedimentary material accompanied by some interchange of constituents. The pyroxene-orthoclase aggregate is coarse-grained, so that there is no sign of chilling at the contact of the igneous rock with the marble.

ORIGIN OF THE ROCKS.—The field relations of the marbles of Assynt and Skye leave no doubt that they are the result of the metamorphism of the "Durness limestone series" in contact with intrusions of various igneous rocks. This calcareous series in the typical locality of Durness includes both dolomites and limestones, but the former appear to predominate both in Assynt and in Skye. Most of the specimens examined accord with the theory that they are metamorphosed dolomites containing a variable amount of silica in the form of chert or quartz, and it will be interesting to consider the facts from this point of view.

Diopside (CaO, MgO, 2 SiO_2) may be formed from dolomite (CaO, MgO, 2 CO_2) by the simple substitution of silica for carbon dioxide, and in accordance with this interchange we find diopside often in direct association with dolomite. Forsterite (2 MgO, SiO_2), on the other hand, cannot be formed in a dolomite, by simple interchange of constituents, without dedolomitisation, and in every case in which this mineral occurs it is associated with calcite. Moreover, there is at any rate a rough general agreement between the amount of forsterite present and the amount of assumed dedolomitisation. In extreme cases no dolomite is left; in others there is only partial dedolomitisation, and the distribution of minerals in the slide accords with the view that the dedolomitisation is due to the development of forsterite. Thus calcite is found surrounding the crystals or crystalline grains of forsterite, while dolomite occurs in the interspaces. The serpentinous rocks illustrate the same principle. The serpentine is mainly if not entirely due to the alteration of forsterite, and is invariably associated with calcite. This suggests the possibility that most of the ophicalcites, including the eozoonal limestone, are altered dolomites.

Tremolite is another mineral invariably associated with calcite in the rocks under consideration, and this fact also accords with the dedolomitisation hypothesis, for the ratio of CaO : MgO is 1 : 3 instead of 1 : 1 as in dolomite and diopside.

It follows as a necessary consequence of the above hypothesis that the contact metamorphism of a siliceous dolomite will not disturb the ratio of CaO : MgO in the mass as a whole; so that if a sufficiently large specimen be taken in the preparation of the sample for the bulk analysis, this ratio should be 1 : 1. To test this a specimen collected about half a mile W.N.W. of the outlet of Loch Lonachan, Skye (6744), was selected and partially analysed by Dr. Pollard with the following results:—

SiO_2	15·96
Al_2O_3	·70
Fe_2O_3	·70
CaO	32·17
MgO	21·43
Ignition	29·22
	100·22

This gives $CaO : MgO = 1·08 : 1$, agreeing with dolomite. The rock is a white saccharine marble containing calcite, forsterite, and a little mica. It was selected not because the relative proportions of the different constituents appeared to be most favourable to the theory but because the constituents, though distributed in bands, were not concentrated in patches or nodules. It is right, however, to add that it would be possible to select specimens from the series in which the amount of lime would be in excess of that required by the theory. Such specimens may indicate either that the original rocks were not true dolomites or that the migration of magnesia has in some cases proceeded to considerable distances.

So far we have been discussing the theory of dedolomitisation consequent on the development of magnesium-silicates. Such a process requires the presence of silica in the original rock, and this is frequently found as chert in the dolomites of Assynt and Skye. But dedolomitisation appears also to be produced in non-siliceous rocks by the formation of periclase or brucite. Both in Skye and Assynt rocks are to be seen composed of brucite and calcite, with a varying admixture of dolomite, forsterite, and serpentine. These rocks are identical with the so-called predazzite which was supposed for some time to be a definite mineral in consequence of the constancy in the ratio of $CaCO_3$ to H_2MgO_2—a constancy equally well accounted for on the theory that the predazzite is an altered dolomite. The evidence that brucite in the rocks from Skye and Assynt is a pseudomorph after periclase has been already referred to. If it be accepted it brings these rocks into close relation with the aggregates of periclase and calcite found amongst the ejected blocks of Monte Somma, which include also eozoonal limestones and other petrological types having affinities with the altered Durness dolomites. The general conclusions arrived at are that the marbles of Assynt and Skye are, for the most part, altered dolomites, and that the alteration has been accompanied by dedolomitisation due either (1) to the development of magnesian silicates such as forsterite and tremolite, or (2) to the formation of periclase or brucite.

PART IV.

POST-CAMBRIAN MOVEMENTS.

CHAPTER XXXII.

GENERAL DESCRIPTION OF THE GEOLOGICAL STRUCTURE OF THE REGION AFFECTED BY POST-CAMBRIAN MOVEMENTS IN THE NORTH-WEST HIGHLANDS.*

The most remarkable feature in the geology of the North-West Highlands is the evidence of terrestrial movements, without a parallel in the British islands, which affected that region in post-Cambrian time. The tectonic structure resulting from these movements is extremely complicated, but the mass of details, obtained in the course of the survey, proves that, while the sections vary indefinitely along the belt of complication for 120 miles, from the north coast of Sutherland to the southern promontory of the Isle of Skye, they nevertheless present certain persistent features, which may be thus summarised:—

1. By lateral compression of the earth's crust the rocks have been thrown into a series of folds, usually inverted, accompanied by several faults or thrusts. The general strike of these folds and dislocations is from N.N.E. to S.S.W. The axial planes of the folds, the reversed faults, and the component beds dip, as a rule, in one direction towards the E.S.E. In the middle limb of the overfold the constituent particles are attenuated, and, along that limb, the overfold may or may not pass into a reversed fault.

2. Without incipient folding, the strata are repeated by a series of minor thrusts or reversed faults, which lie at an oblique angle to more important dislocations, termed by us major thrust-planes. They are likewise inclined to the E.S.E.—the direction from which the pressure proceeded. (Imbricate Structure, *Schuppen Struktur.*)

3. By means of major thrusts of varying magnitude, striking generally N.N.E. and S.S.W., the following structures have been produced:—(*a*) Certain sub-divisions of the Cambrian system have been heaped up and driven westwards along planes

* By J. Horne.

produced in underlying undisturbed materials; (*b*) masses of Lewisian gneiss with its unconformable covering of Torridon Sandstone and Cambrian strata override the piled-up strata beneath; (*c*) the Eastern schists have been thrust far to the west, till, in some instances, they rest directly on undisturbed Cambrian rocks.

4. Owing to the travelling of the rocks from east to west and also to the friction along the unyielding lower plane or "sole" of the thrust, there was a tendency in the materials to fold over and curve under, thus producing inversion.

5. While the planes of the major thrusts, along which the materials have been driven, usually dip at low angles to the E.S.E., yet they are frequently irregular both in direction and angle of inclination.

6. The outcrops of the major thrust-planes resemble boundary-lines between unconformable formations because (1) there is always a complete discordance between the strata lying above and below the planes of disruption, and (2) each successive thrust may be overlapped in turn by a higher one.

7. Thrusts of smaller magnitude, when followed along the strike, may merge into folds.

8. By means of denudation, outliers of the materials lying above the planes of disruption have been formed, as, for instance, where patches of Lewisian gneiss, Torridon Sandstone, and Cambrian quartzites rest on the *Olenellus* zone or on Cambrian dolomite and limestone, the upper discordant members being separated from the lower by a fault with a circular outcrop.

9. The more powerful displacements were accompanied by differential movement of the materials which resulted in the development of new structures.

CLASSIFICATION OF THE STRUCTURES.

The several types of structure observable along the belt of complication have definite relations to each other in the field, and occur in consecutive order from west to east. From this point of view, the structures may be arranged in two divisions—(*a*) those which occur in advance of, or to the west of, the great lines of disruption; (*b*) those immediately associated with each of the powerful thrusts which have produced extensive displacement of the strata.

i. *Structures in advance of the Great Lines of Disruption.*—These are confined to the belt of complication that generally intervenes between the undisturbed area to the west and the outcrop of the great thrust-planes to the east. This stage in the history of the movements is represented by two well-marked types.

The first of these is characterised by the constant reduplication of sub-divisions of the Cambrian series, or of Cambrian and Torridonian strata combined, mainly by inverted folds, and to a limited extent by reversed faults or minor thrusts. This system is well illustrated in the mountainous region between Loch Maree and Strath Carron, where the same zones, consisting of the Cambrian quartzites with the underlying Torridon Sandstone, are repeated chiefly by isoclinal flexures dipping E.S.E. The repetition of these beds by this method extends over a belt several miles in width in parts of that region. (Figs. 49, 50, 51, 52, 53.) Again, in Skye, overfolding is more characteristic of the areas in advance of the great thrusts than reversed faults. (Fig. 61.)

The second type presents important points of difference from that just described. In this system the Cambrian zones are repeated by minor thrusts without incipient folding. Lower zones are made to rest on higher beds by means of reversed faults, the latter being inclined at a slightly higher angle than the dip of the strata. Save in exceptional instances, the beds between each reversed fault preserve their normal order of succession and have a persistent dip to the E.S.E., thus furnishing an example of imbricate structure (*Schuppen Struktur*). The slices of strata, thus repeated, have been driven westwards by major thrusts along planes, which truncate the overlying reversed faults, and nearly coincide with the lines of bedding of the sediments over considerable distances. This type has a remarkable development in Sutherlandshire from the eastern shore of Loch Eireboll to the southern limits of Assynt, though with somewhat varying features.

In certain areas, as, for instance, at Heilim in Loch Eireboll, and on the shores of Loch Glendhu and Loch Glencoul, north of Inchnadamff, the strata repeated by this system of reversed faults consist of fucoid-beds, *Salterella-* (serpulite-) grit, and basal dolomite, the whole thickness of sediments not exceeding 100 feet. In these sections, the observer may traverse continuous exposures for long distances, showing the recurrence of these zones in successive slices, in which the beds preserve their normal sequence. (Figs. 20, 28, 29, 31.) This type of structure has been successfully reproduced experimentally. Further examples of it occur in the plateau east of Elphin in the southern part of Assynt, and also at Courthill east of Loch Kishorn, where the Cambrian dolomites and limestones, repeated by reversed faults, have been made to cover extensive areas. (Figs. 39, 55.)

Perhaps the most striking instance of the driving together of the Cambrian zones by this system of movements is to be found in the mountainous region between Loch More and the head of Loch Eireboll, where the basal quartzites and pipe-rock have been piled up by minor thrusts, all oblique to an underlying thrust-plane and inclined to the E.S.E. The section (Fig. 25) from Creag Dionard across the Plat Reidh shows how, by this kind of displacement and repetition, a deceptive stratigraphical sequence is produced, together with an apparent thickness greatly in excess of the real depth of the strata. In all these examples of imbricate structure the resistance to the development of folds was obviously greater than the resistance to the

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formation of thrust-planes. It has sometimes happened that the structures characteristic of this phase of the movements have been buried underneath the materials overlying the great thrust-planes so as not to appear at the surface along the belt of complication; but wherever denudation has laid bare a portion of this belt, these structures are met with.

ii. *Structures Characteristic of the Great Thrusts.*—These structures may also be arranged in two groups in accordance with the nature of the materials that have been driven westwards. In the first or more westerly group, these materials consist of Lewisian Gneiss, Torridon Sandstone, and Cambrian strata, or of the first and last of these three great systems of rock, without any representative of the middle member. In the second group, which accompanies the Moine thrust, or most easterly of the great movement-planes, the displaced materials are composed of quartz-schists, mica-schists, garnetiferous muscovite-biotite-schists, and lenticular masses of acid and basic gneisses of Lewisian types.

The structures displayed in the first group, when exposed, always lie to the west of the Moine thrust-plane along the whole belt of complication from Loch Eireboll to Sleat in Skye. For convenience of description, the several major thrusts among them have received local names, from the districts where they are typically developed (Arnaboll, Glencoul, Ben More, Kinlochewe, Kishorn, Ben Suardal). In some areas only one of these powerful thrusts is represented, in others two or more occur, as in Assynt, where the Glencoul and Polandroighinn displacements are overlapped by that of Ben More. Although these lines of disruption cannot be traced continuously along the belt of complication, yet it is probable that some which have received distinct names may really be identical—that, for example, the Ben More, Kinlochewe, and Kishorn displacements lie on the same horizon. The evidence further points to the conclusion that the Kishorn line of movement is prolonged into Sleat in Skye.

It is a remarkable fact, which has an important bearing on the theoretical question of the origin of the Moine-schists (Eastern schists), that the Torridon Sandstone never occurs in any of the displaced masses west of the Moine thrust between Loch Eireboll and the Ben More Assynt range—a distance of 34 miles. The materials brought forward by the great lines of disruption in advance of the Moine thrust in that portion of the belt consist solely of Lewisian gneiss and Cambrian strata. A striking feature of these displacements is observable in the vast thickness of the slice of the old Archæan floor that has been superimposed on the piled-up Cambrian rocks. Near Glencoul it must be, at least, 1500 feet thick, and in that region it has borne westward all the Cambrian zones in succession from the false-bedded quartzites to the dolomite and limestone. (Fig. 28.) When the Glencoul line of movement is traced southwards into Assynt, the thin veneer of quartzites on the crest of Glasven is found to fold over and to buckle under the western face of displaced gneiss which there rests in inverted order on that thrust-plane. (Fig. 31.)

A careful examination of the displaced masses in advance of the Ben More thrust in the northern part of Assynt shows that the Lewisian rocks form the core of a series of compound folds overlain by the Cambrian quartzites which have been driven west along the Glencoul plane of movement. (Figs. 31, 32.) The same system of folding on this horizon is doubtless prolonged northwards to Eireboll, though the quartzites overlying the displaced gneiss on the crests of the folds have been largely removed by denudation. (Figs. 21, 22, 24.)

In the southern portion of the belt between Ben More Assynt and Skye, the Torridon Sandstone is always represented in the displaced masses brought forward by the powerful lines of disruption in advance of the Moine thrust. It further appears that the slices of this formation increase in thickness southwards in the direction of Skye. Indeed, in Sleat, the belt of thrust Torridon Sandstone is several miles in breadth, and the thickness of the various groups represented, if there is no reduplication of the strata by folding, must be about 5000 feet. (Figs. 59, 60, 61.)

It is worthy of note that the system of plication which occurs above the Glencoul line of movement is repeated on a still grander scale above the Ben More thrust-plane in Assynt. A vast slice of Lewisian rocks, more than 1500 feet thick, overlain by Torridonian and Cambrian strata, forms there a great dome-shaped flexure with the unconformable sediments arranged in inverted order beneath the displaced gneiss. On the eastern ridge of Ben More the thin covering of quartzites on the crest of the fold has been largely removed, but on Sgonnan More, and particularly on its southern slope, the arch is seen in a less-advanced stage of decay. (Figs. 32, 33, 34, 35, 36.)

Again, from Kishorn southwards into Sleat, the most striking feature of the tectonics of the displaced materials on this horizon is the great inversion of Torridon Sandstone; this formation in the neighbourhood of Stromeferry being overlain by the overturned floor of Lewisian gneiss. The horizontal sections (Figs. 55, 56, 57) show that this inversion forms part of a great fold which has been driven westward along the Kishorn thrust-plane. On the mainland south of Kishorn the Cambrian quartzite is never seen in visible connection with the thrust Torridon Sandstone, but the unconformable junction between the two appears in Sleat between the Ord and Tarskavaig, where a normal sequence can be followed upwards to the *Olenellus* zone.

The southern portion of the belt of complication between Assynt and Sleat affords conspicuous examples of the plication of the great movement-planes in advance of the Moine thrust, and of the subsequent denudation and isolation of masses of material that overlie these planes. (Figs. 36, 48, 49.) In Sleat a remarkable instance may be seen of the reversal of the west limb of the anticline of the Sgiath Bheinn an Uird thrust, with the folded and thrust Cambrian rocks in the core of the flexure. (Fig. 62.) It is highly probable that the production of these flexures was coincident with the advance of the Eastern schists, and may have been caused by the pressure of that advancing mass. At the same time, it must be remembered that in Skye evidence has been obtained of the post-Jurassic folding of one of these early Palæozoic thrust-planes. The Ben Suardal thrust appears to have shared in the folding of the Mesozoic strata which curve round the north end of that hill.

Reference has already been made to the overlap of the Ben More thrust in Assynt, where it passes transgressively across powerful displacements to the west. Immediately to the north of Kinlochewe the transgression is still more apparent, for the slice of Lewisian gneiss, which has there been borne westward by the Kinlochewe thrust, oversteps all the underlying piled-up strata, so as to rest directly on the undisturbed fucoid-beds. (Figs. 47, 48.)

The second group of great lines of disruption, which is represented by the Moine thrust, differs, as already indicated, from all others to the west in the crystalline condition of the materials which it has transported westwards. These materials forming the crystalline schists of the Moine series, and comprising quartz-schists, quartz-biotite-granulites, garnetiferous mica-schists, and limestones, evidently represent altered sediments the age of which is still uncertain. It will be shown in later chapters that recognisable zones of the Torridon Sandstone pass into rocks of intermediate type with structures akin to those of the granulitic schists of the Moine series, and that sills of igneous material resembling some of the igneous rocks intrusive in the Cambrian strata of Assynt are intercalated in the Moine schists and have shared in the movements that have affected them. At the same time, it should be mentioned that in some districts, as between Stromeferry and Loch Alsh and again in Sleat in Skye, the structures of the Moine schists have been broken down by the post-Cambrian movements, as if some, at least, of these rocks were already crystalline before being brought into their present positions.

The Moine thrust is perhaps the most important structural feature produced by the post-Cambrian movements in the North-West Highlands. Though, owing to the development of mylonites in association with this line of disruption, it is extremely difficult to determine everywhere its exact position, yet at various places between the north coast of Sutherland and Sleat the plane of movement has been laid bare, and its gentle angle of inclination to the E.S.E. can be definitely ascertained. A marked characteristic of the Eastern schists is seen in their double system of folding, evidently produced by the same series of earth-stresses; one set of flexures trending N.N.E. and S.S.W., in harmony with the general strike of the rock groups, and the other set W.N.W. and E.S.E. in the line or direction of the post-Cambrian movements. Another remarkable feature of these rocks is their extraordinary overlap across all underlying thrusts and displaced masses till they rest directly on the undisturbed Cambrian rocks to the west. The extreme narrowness of the belt of complication between Knockan in Sutherlandshire and Loch an Nid in the Dundonnell Forest in Ross-shire—a distance of 24 miles—is due to the transgression of the Moine schists along that thrust-plane. Along their present western limit the Eastern schists form a thin veneer covering either undisturbed Cambrian strata or thrust Lewisian, Torridonian, and Cambrian rocks. (Fig. 40.)

EXTENT OF HORIZONTAL DISPLACEMENT OF THRUST MASSES.

Fortunately direct evidence is obtained in certain areas of the minimum extent of the horizontal displacement of materials by the post-Cambrian movements. In the extreme north of Sutherland the various rock-groups included under the Eastern schists, and overlying the Moine thrust-plane, can be shown to have been driven westwards for a distance of ten miles from the hill-slopes on the east side of Loch Eireboll to the centre of the Durness basin and the promontory of Far-aird Head. (See geological map.) Again, near the county boundary between Sutherland and Ross, the great overlap of the Eastern schists can be traced continuously for a distance of six miles across the broad belt of folded and thrust materials in the Assynt mountains. Further evidence is furnished by the masses of Lewisian gneiss which have been driven westwards in advance of the Moine thrust. It seems to be a general rule that the types of gneiss in the displaced masses occur several miles to the south of corresponding types in the undisturbed areas to the west. The most remarkable example of this tectonic feature is to be found in the Glencoul district, where the thrust gneiss with broad veins of red pegmatite and basic dykes has been shifted southwards for a distance of six miles from Ben Stack to Glencoul. As the general trend of the basic dykes is north-west and as the direction of the post-Cambrian movements is W.N.W., it is obvious that the gneiss must have been thrust several miles from the E.S.E. Similar evidence is obtained in the Kinlochewe district of Ross-shire, where the displaced gneiss overlying the Kinlochewe thrust-plane presents original characters like those of Cadha Beag, near Gruinard, in the undisturbed area several miles to the north. It is further obvious that the driving together of the Cambrian zones resulting in imbricate structure (*Schuppen Struktur*) represents great lateral displacement of the zones, though it is difficult if not impossible to form any reliable estimate of its extent.

METAMORPHISM RESULTING FROM THE POST-CAMBRIAN MOVEMENTS.

The great terrestrial displacements were accompanied, within certain limits, by differential movement of the materials which resulted in the development of new structures. These phenomena become more pronounced as the rocks are traced eastward from the undisturbed area. They are highly developed along the belt of rocks in immediate association with the Moine thrust, where the outcrop of the plane of this great dislocation lies to the east of a broad belt of displaced materials. It is worthy of note that among the Cambrian strata heaped up by reversed faults (*Schuppen Struktur*) in advance of the great lines of disruption, no metamorphism of any importance is observable, though there must have been considerable friction of the materials in the process of displacement.

The first appearance of the development of new structures east of the undisturbed area which flanks the belt of dislocation on its western side occurs in association with the chief planes of movement. The more westerly displaced masses of Lewisian gneiss have suffered little deformation save in immediate contact with the thrust-planes (Glencoul, Ben More, Kinlochewe), where the gneiss has usually been sheared. Again, along the line of unconformable junction between the thrust Lewisian rocks and Torridon Sandstone or Cambrian quartzite, the old structures of the gneiss have been effaced and differential movement of the constituents has taken place.

When, however, we pass eastwards to the belt of deformed rocks lying immediately in front of the Moine thrust or resting on its "sole" or plane of movement, the Lewisian gneiss merges into flaser-gneiss and schist and ultimately into a banded rock like platy schist. The pegmatites show fluxion-structure like that of rhyolites, with felspar "augen." These mylonised rocks present a variegated appearance, being red, green, or grey, according to the character of the original material from which they were derived. Good illustrations of these phenomena may be seen on the east side of Loch Eireboll and in the hilly region between Stromeferry and Loch Alsh. In all these examples of crushed material the planes of deformation lie more or less parallel with the great planes of movement.

The Torridonian conglomerates, grits, sandstones, and shales have also been affected by the post-Cambrian movements, particularly along the inverted limbs of the great overfolds. For example, in the Oykell valley, in the Ben More-Assynt region, where the basal conglomerate lies in inverted order beneath the Lewisian gneiss, its pebbles have been crushed, flattened, and elongated in the direction of movement, and a fine schistose or wavy structure has been developed in its matrix. Cleavage has been superinduced in the other sediments, the beds of coarse grit being less distinctly cleaved and the planes being more highly inclined than those in the finer sandstones and shaly bands. Occasionally lenticular veins of pegmatite occur, arranged in lines more or less parallel with the new schistose planes.

Again, along the great inversion at Fernaig, south of Stromeferry, foliation has been developed in the Torridon basal conglomerate and overlying Lewisian gneiss parallel with the axial plane of the overfold and with the plane of the Moine thrust. On this horizon, also, between Kishorn and Loch Alsh, and in the Coulin Forest, south of Kinlochewe, the development of new structures in the Torridonian sediments by the post-Cambrian movements is well marked. Dr. Teall has shown that the quartz-grains have been drawn out into thin folia that wind round "eyes" of felspar. A secondary crypto-crystalline material has been produced, sericitic mica appears in the divisional planes, and in some instances biotite has been developed.

The deformation of the Cambrian strata is no less conspicuous in the northern part of the belt of complication either in contact with the Moine thrust-plane or in the thrust-masses in advance of it. In the case of the basal false-bedded grits or quartzites, the pebbles of quartz and felspar have been elongated, the felspar having been often fractured and traversed with veins of secondary quartz. The vertical "pipes" or annelide-tubes in the pipe-rock have been bent over, flattened, and drawn out into ribands parallel with the direction of movement. Where these changes of form are observable muscovite has been abundantly developed and the strata have assumed the appearance of quartz-schists. Fine parallel lines, trending generally E.S.E. and W.N.W., appear on the new divisional planes, in accordance with the general direction of the post-Cambrian movements.

Further evidence of deformation is supplied by the series of intrusive sills in the successive thrust-masses in Assynt. The sheets of felsite in the basal quartzite above the Ben More thrust-plane have been converted into soft sericitic schists, the fine hornblende-porphyrites in the limestones pass into green chloritic schists, and the albite-porphyrites present the appearance of augen-schists. These changes become more pronounced as the rocks are followed eastwards to the Moine thrust.

PROBABLE SEQUENCE OF THE MOVEMENTS.

The various lines of evidence available lead to the conclusion that the pressure which gave rise to the overfolding and great displacements of the rock-masses came from the E.S.E. We may now consider the probable sequence of the earth-movements.

In the Reports which were published in 1884* and 1888†, it was implied that the structures first produced were those in advance of the great lines of disruption, and that the latter arose in sequence from west to east, the Moine thrust being the last of the series. But some of the data furnished by Mr. Cadell's experiments, which are referred to in the sequel, together with the field-evidence obtained in the Dundonnell Deer Forest,

* *Nature*, Nov. 13th, 1884.

† *Quart. Journ. Geol. Soc.*, vol. xliv. (1888), p. 378.

suggest the probability that the reverse order may have been the case, as was originally maintained by Professor Lapworth.*

From Mr Cadell's experiments it would appear that "the horizontal pressure is not propagated far forward into a mass of strata," and that the structures first produced override the subsequent ones. If this be the true order of appearance, it would seem that the Moine thrust was the first of the great lines of disruption to be produced, and that, on the continuation of the pressure, the force was successively communicated to masses further to the west. Thus the imbricate structure (*Schuppen Struktur*) found at intervals along the western edge of the belt of complication may indicate a late stage in the evolution of the structure of the region. But, though such may have been the case, it is obvious that the westerly movement of the Eastern schists that overlie the Moine thrust-plane must have been continued after the inception of the *Schuppen Struktur*, for, as we have seen, these schists override all the displaced masses and rest directly on the undisturbed Cambrian rocks. Indeed, the wedges of piled-up strata showing imbricate structure may be said to have acted like rollers for the transport of advancing masses on higher thrust-planes.

The evidence obtained in Dundonnell Forest, south of Loch Broom, which is described in Chapter XXXVI., seems to have an important bearing on the question under consideration. In that area a denuded anticline runs for several miles in an E.N.E. direction, and affects alike all the displaced masses and thrust-planes, from the Eastern schists at the top to the heaped-up strata in advance of the Ben More thrust beneath. These materials rest on a plane or "sole" formed by the underlying undisturbed Cambrian rocks. (Fig. 45.) The inference seems reasonable that, after the inception of the Moine thrust and the Ben More thrust, and after the piling-up of the strata in advance of the latter, all the displaced materials moved westwards along the lowest thrust-plane or "sole." Eventually the friction in advance of the area represented in Fig. 45 accumulated to such an extent as to produce a sharp plication of all the structures overlying this "sole."

In discussing the sequence of events in the development of the structure of the North-West Highlands, we are confronted with the complications that must have arisen from the effects of increasing load due to the heaping-up of the advancing masses. Further, it ought to be borne in mind that denudation has exposed at the present surface structures which were produced at varying depths and under different conditions of load.

AGE OF THE MOVEMENTS.

It is obvious that the movements here under consideration must be later than the Cambrian dolomites and limestones and

* "The Close of the Highland Controversy." *Geol. Mag.*, New Series, Dec. iii., vol. ii., p. 105.

the igneous rocks intrusive in the sub-divisions of that system in Assynt. In the opinion of Dr. B. N. Peach, the fauna obtained at Durness is similar to, if not identical with, that which in Newfoundland, Mingan Islands, and Point Levis is found beneath strata that yield the Arenig *Phyllograptus* fauna, and is therefore of Cambrian age. On the other hand, the movements must be much older than the Old Red Sandstone, for its basal conglomerates rest unconformably on a denuded surface of the Eastern schists, and contain pebbles of basal quartzite, pipe-rock, dolomite, and limestone derived from the Cambrian rocks of the North-West Highlands.

EXPERIMENTAL RESEARCHES BY MR. H. M. CADELL.

The remarkable structures described in the previous paragraphs led Mr. H. M. Cadell, formerly a member of the Geological Survey, to institute a series of experiments* with the view of imitating in the laboratory processes which may have been in operation during the development of the post-Cambrian movements in the North-West Highlands. A study of the phenomena in the field had shown that, in some cases, the rocks of that region behaved like brittle rigid bodies under the influence of horizontal compression or earth-creep, and that, instead of undergoing plication, they had snapped across and been piled together in slices like so many cards swept into a heap on the table. To imitate such structures, Mr. Cadell made use of plaster of Paris interleaved with damp sand, which set into hard brittle laminæ that snapped under strain, and in some instances allowed folding to take place. In some of the experiments black foundry-loam was employed, and in others clay, usually in association with less plastic layers.

The experiments were of three kinds. The first series (*a*) was designed to explain the behaviour of different types and arrangements of strata when pushed horizontally over an immovable surface; the second (*b*) to ascertain if possible how gently-inclined thrust-planes may have originated, and to trace their connection with fan-structure and other phenomena observed in mountain systems of elevation; and the third series (*c*) was conducted on principles suggested by the experiments of Favre, who placed layers of clay on a stretched indiarubber band, which, on contraction, produced miniature mountain ridges by the wrinkling of the surface of the clay.

In the course of his experimental researches, Mr. Cadell successfully reproduced two types of structure which are characteristic of certain stages of the post-Cambrian movements in the North-West Highlands—(1) the imbricate structure (*Schuppen Struktur*), and (2) the inclined thrust-plane or "sole" along which the heaped-up slices were driven.

* *Trans. Roy. Soc. Edinb.*, vol. xxxv., Part VII.

In the experiment that illustrated the first of these two types the depth of strata was only $1\frac{3}{4}$ inches, the breadth 8 inches, and the section was pressed in from an original length of 44 inches to a space of 15 inches. In the initial stage, horizontal force being applied at one end, a small overfold was produced, but afterwards the layers or strata underwent a process of piling-up in separate slices by slightly-inclined reversed faults. The accumulating mass slipped vertically up the face of the pressure board as each new wedge of material snapped and was driven under the piled-up layers. The accompanying Fig. 19*a* is a diagrammatic representation of the structure thus produced.

FIG. 19*a*.—Development of Imbricate Structure. (H. M. Cadell.)

In another experiment it was found that, after continued heaping up of the materials, the displaced layers rose and slid forward along a major thrust-plane or "sole" which truncates the overlying minor thrusts or reversed faults. (Fig. 19*b*). It is apparent that beds repeated in this manner in the field, without inversion or folding, might simulate a normal sequence of strata of great thickness.

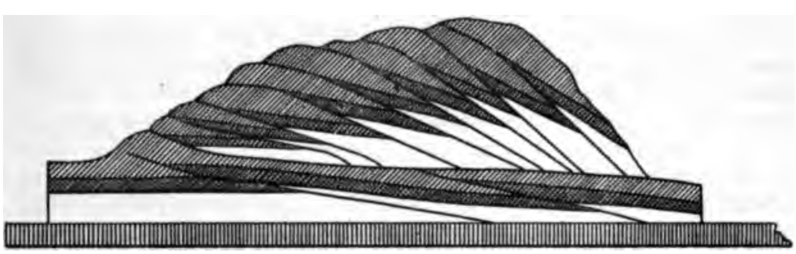

FIG. 19*b*.—Major thrust-plane or "sole." (H. M. Cadell.)

These experiments furnish some suggestive indications of the order in which the various structures were developed. It is obvious that the wedges first piled-up are those nearest the compressing force, and that after the continuance of the heaping up for an indefinite period the major thrust-plane or "sole" is produced.

In another illustrative experiment, instead of the pressure board being held in a vertical position, with its lower end against the fixed sole, a cushion of sand was substituted for it and force was applied behind. The result showed that the whole mass rose and slid forward over the lower and less-disturbed beds along a major thrust-plane, inclined at a very slight angle to the horizon. During the forward movement the friction tended to retard the front more than the back part of the advancing mass, thereby increasing the inclination of the thrust layers. Had the experiment been continued, the originally horizontal parts of the thrust mass would doubtless have become vertical, thereafter bending inwards towards the major thrust-plane below. (Fig. 19*c*.)

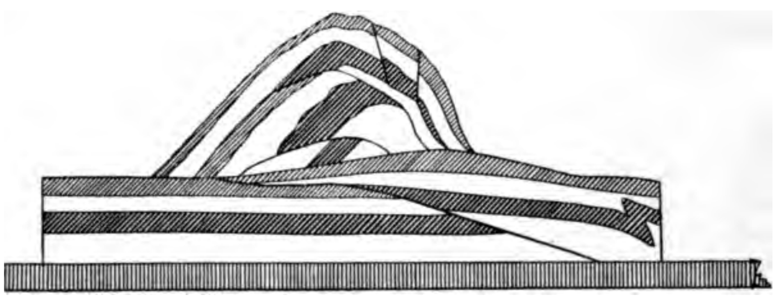

Fig. 19c.—Folding of Thrust Materials along a Major Thrust-plane. (H. M. Cadell.)

At the conclusion of his paper from which these notes and illustrations are taken, Mr. Cadell thus summarises the results of his researches:—

1. Horizontal pressure applied at one point is not propagated far forward into a mass of strata.
2. The compressed mass tends to find relief along a series of gently-inclined thrust-planes, which dip towards the side from which pressure is exerted.
3. After a certain amount of heaping-up along a series of minor thrust-planes, the heaped-up mass tends to rise and ride forward bodily along major thrust-planes.
4. Thrust-planes and reversed faults are not necessarily developed from split overfolds, but often originate at once on application of horizontal pressure.
5. A thrust-plane below may pass into an anticline above, and never reach the surface.
6. A major thrust-plane above may, and probably always does, originate in a fold below.
7. A thrust-plane may branch into smaller thrust-planes, or pass into an overfold along the strike.
8. The front portion of a mass of rock being pushed along a thrust-plane tends to bow forward and roll under the back portion.
9. The more rigid the rock, the better will the phenomena of thrusting be exhibited.

10. Fan-structure may be produced by the continued compression of a single anticline.
11. Thrust-planes have a strong tendency to originate at the sides of the fan.
12. The same movement which produces the fan renders its core schistose.
13. The theory of a uniformly contracting substratum explains the cleavage often found in the deeper parts of a mountain system, the upper portion of which is simply plicated.
14. This theory may also explain the origin of fan-structure, thrusting, and its accompanying phenomena, including wedge structure.

CHAPTER XXXIII.

GEOLOGICAL STRUCTURE OF THE GROUND FROM DURNESS AND EIREBOLL TO LOCH MORE.*

The district to be described in the present chapter extends from the northern coast-line of Sutherland, between the Kyle of Durness and the ground east of Loch Eireboll, southward to the line of valley in which Loch More lies, and is represented on Sheets 107, 108, 113, and 114 of the one-inch map. It exhibits with great clearness the main tectonic features in the complicated structure of the North-West Highlands. Among these features, the following are typically displayed:—

(1) The reduplication of the Cambrian strata by means of reversed faults and folds in advance of the great lines of displacement.

(2) The occurrence of two powerful thrusts, the more westerly one on Ben Arnaboll, bringing forward a slice of the old floor of Lewisian gneiss, together with the overlying unbroken Cambrian sequence from the basal quartzites to the Eilean Dubh dolomite (Group II. of the Calcareous Series), and the more easterly or Moine thrust ushering in the "Eastern or Moine schists."

(3) The remarkable overlap of the Moine thrust, whereby the materials which rest upon that plane pass transgressively across all underlying displaced masses till they come to repose directly on the highest division of the Calcareous Series in the Durness basin.

(4) The existence of a double system of normal faults affecting the strata and thrust-planes alike, one set trending N.N.E. and S.S.W., while the other, which appears to be newer, runs more or less at right angles to the first series. By these two systems of later dislocations the thrust-planes, lying at gentle angles, have been intersected and shifted precisely as if they had been boundary-planes between two geological formations. By means of two normal step faults, the Cambrian basin of Durness and the mass of Eastern schists which lies upon it have been isolated from the main belt at Eireboll, and have been brought down to the sea-level.

* By B. N. Peach and J. Horne, with notes supplied by H. M. Cadell.

(a) *The Durness Basin.*

The general structure of this important district is illustrated by the sections in Figs. 20 and 23. The western portion of ground represented in Fig. 20 shows the slightly uneven surface of Lewisian gneiss (A) on which the Torridon Sandstone (Bb) was laid down, the unconformability between these red sandstones and the overlying Cambrian quartzites (Ca), and the isolation of portions of these sedimentary systems by denudation.

On Meall Sgribhinn, the basal quartzites (Ca) and part of the pipe-rock (Cb) dip to the south of east at angles varying from 12° to 18°, while the underlying red sandstones are almost flat or gently inclined to the north-west. Passing eastwards to the shore of the Kyle of Durness at Dail, we find an example of the double unconformability, for the basal beds of the Arenaceous Series (Ca) rest partly on the red sandstones (Bb) and partly on the Lewisian gneiss (A, Fig. 20). Beyond a small fault that repeats the base line at Dail, the transgression is complete, for the false-bedded Cambrian grits there rest directly on the ancient floor of Lewisian gneiss (A in Fig.).

Though the normal sequence from the pipe-rock sub-zones to the fucoid-beds and *Salterella*- (Serpulite-) grit is not exposed near Dail, the outcrops of the members of the Middle Series being concealed by the waters of the Kyle, it is found in the southern portion of the basin, as already mentioned, at Rudh' a' Ghrudaidh. Between the east shore of the Kyle and the village of Durine, the seven groups of the Calcareous series (Ce I.-VII.) succeed each other in natural order, although their outcrops have been shifted by several faults. It is noticeable, however, that cleavage begins to appear in the more fine-grained members of the Balnakiel sub-division, and becomes more pronounced in the overlying zones. The outcrops of the higher zones of dolomite and limestone are repeated by a series of strike-faults, some of which can be proved to be normal, others may possibly be reversed.

East of the village of Durine, the highest members of the Calcareous series are overlain by shattery quartzite, striped fissile schist, frilled schist, and deformed gneiss (M′ λ. A), which together form part of the series above the Moine thrust-plane (T′). Their superposition is clearly displayed in the cliff west of Sango Bay, to the south of Creag Chearbach, where the rocks beneath and above the thrust-plane are alike affected by small normal faults. The development of these ancient displaced rocks in this part of the basin is limited, for they stretch southwards only for about a mile, and along their eastern margin they are abruptly truncated by a powerful dislocation (f_2 in Fig. 20), which lets them down against the Sailmhor dolomites. (Ce III.) The apparently conformable sequence from the Calcareous series into an overlying series of schists is entirely deceptive, for these schists can be linked with the corresponding section at Fair-aird

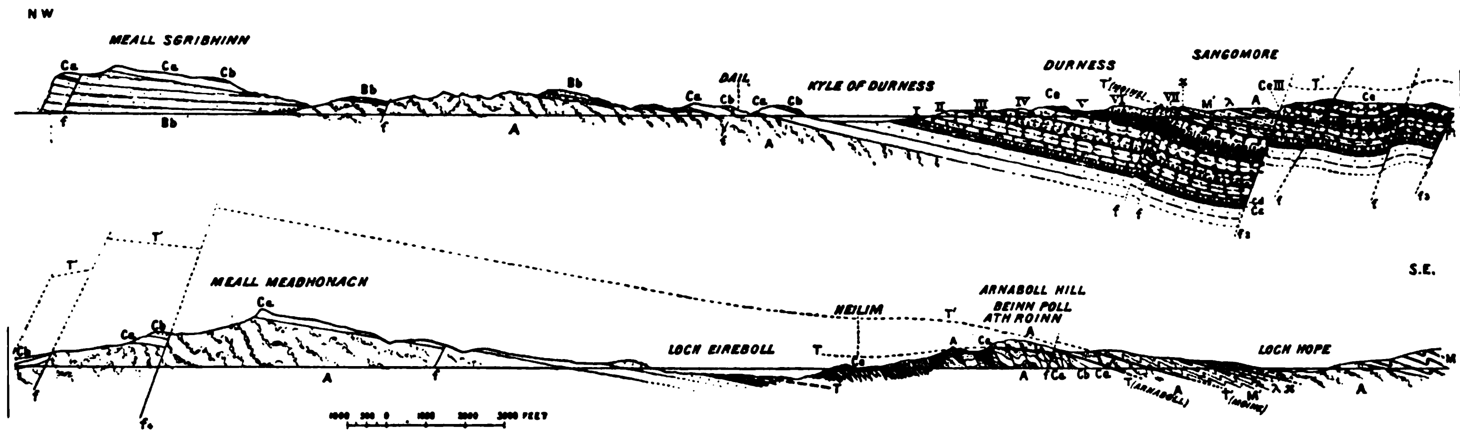

FIG. 20.—Section from Meall Sgribhinn by Durness, Sangomore, and Meall Meadhonach to Arnaboll Hill and Loch Hope.

A. Lewisian Gneiss. Bb. Torridon Sandstone. Ca. Basal Quartzite (Cambrian). Cb. Pipe-rock. Cc. Fucoid-beds. Cd. Serpulite Grit. Ce. Limestone. Ce I. to Ce VII. Cambrian Dolomite and Limestone. M′. Mylonized Rocks, Green Schists, and Phyllites. M. Moine-schists. x. Quartz Schist. λ. Marble. T. Thrusts. T′. Moine-thrust. f. Faults.

Head, north-west of Durine village, and with the sequence overlying the Moine thrust-plane east of Loch Eireboll. (See Fig. 23.)

On the further side of the limestone plateau east of Sangomore the dolomites and limestones of Group IV., there broadly developed, are bounded by a fault (f_3 in Fig. 20), which successively brings them in contact with the pipe-rock (Cb) and basal quartzites (Ca) skirting the shore west of Sangobeag. On the western slope of Meall Meadhonach, about the level of the 900-feet contour line, a small outlier of the basal quartzites (Ca) with part of the pipe-rock (Cb) rests on the Lewisian gneiss, and is cut off along the eastern margin by the first of the two great step faults that bring down the Durness basin (Sheet 114).

(b) *Loch Eireboll.*

The platform of Lewisian gneiss (A) on the eastern slope of Meall Meadhonach is covered unconformably by a thin cake of basal quartzites (Ca), followed on the west shore of Loch Eireboll by the pipe-rock (Cb). Crossing the loch to Heilim, the observer immediately encounters the belt of complication in advance of the Arnaboll thrust. Nowhere in the Eireboll region is the development of imbricate structure ("Schuppen-struktur") so clearly displayed as in the fine coast-section from Heilim northwards to the mouth of the Hope River. For about a third of a mile north of the ferry-house the two lowest groups of the Calcareous series are repeated, but further north for a distance of a mile and a half there is a constant reduplication of fucoid-beds, serpulite-grit, and basal dolomite in thin lenticular masses, repeated by reversed faults. The inclination of these displacements is at a slightly higher angle than the dip of the strata, the difference varying from 10° to 15°, and a similar relationship is observable between the planes of cleavage and of stratification in the fucoid-beds. Both the strata and the reversed faults are inclined to the E.S.E. at rather high angles. At Cailleach a 'Mhuilleir, the headland about a mile west of the mouth of Hope River, these piled-up beds are cut off by a thrust inclined to the E.S.E. at 50°, which brings up the pipe-rock to the east. Beyond this dislocation the Cambrian strata are repeated by folds as well as by reversed faults, as may be seen round Beinn Heilim, where the beds consist chiefly of pipe-rock, though some of the hill-tops are capped by fucoid-beds with infolds of serpulite-grit.

Between Heilim and the base of Arnaboll Hill (Beinn Poll Ath roinn in one-inch Sheet 114), all the zones, ranging from the Eilean Dubh dolomites to the pipe-rock, are repeated by a complicated system of reversed faults and folds, the higher zones occurring to the west and the lower ones to the east. Round the western slope of that hill the arrangement of the fucoid-beds, serpulite-grit, and basal dolomite admirably illustrates the piling-up of the rocks in advance of the more powerful lines of disruption. At length this system of faults and folds culminates in the Arnaboll thrust, by which a mass of Lewisian gneiss, in places upwards of 400 feet thick and presenting features similar to those west of Eireboll, has been driven over the Cambrian strata. The detailed mapping of the displaced gneiss on Beinn Arnaboll proves it to rest transgressively on all the Cambrian zones from the basal quartzites to the *Salterella* dolomite (Group I. of the Calcareous series). This discordance was recognised by Nicol, who regarded the gneisses as granulites intrusive in the Cambrian sediments.

The effects of this disruption on the quartzites is well seen on Beinn Arnaboll. (Fig. 20.) On the north slope, where the pipe-rock (Cb) underlies the gneiss (A), the vertical worm-tubes are flattened and bent over in the direction of the plane of movement; and on the eastern declivity, where the basal quartzites are covered by the Archæan rocks, they develop a finely-banded and streaky appearance, due to the compression of the felspar fragments and grains of quartz. On the surface of the divisional planes a series of parallel lines indicates the direction of movement, and is accompanied by a slight development of white mica. In like manner the Lewisian gneiss (A), while preserving its original structures in the heart of the mass, is highly sheared in places near the plane of disruption. The production of pseudo-rhyolitic structure in the pegmatites, and the conversion of the hornblendic gneiss into a green micaceous schistose rock, are displayed on the eastern slope where the Lewisian rocks overlie the basal quartzites.

The former further north-westward extension of the displaced gneiss is proved by the occurrence of a small outlier, about 100 yards long, on the crest of a hill (Sithean-na-Cuag) about half a mile north-west of Beinn Arnaboll and 300 yards west of Loch Creagach, where the thrust materials consist of sheared gneiss and rest on the fucoid-beds, serpulite-grit, and dolomite. (Shown on Fig. 20.) The mass of Lewisian gneiss on Beinn Arnaboll is abruptly cut off by the Moine thrust (T_1 in Fig.) which ushers in the Eastern schists. The peculiar green platy mylonised rocks, the frilled schists, marble, deformed gneiss, and siliceous Moine schists (M′, λ, A, M) which occur in Sango Bay and round Fair-aird Head (Durness) are here conspicuously developed.

The evidence being thus clear for the complete discordance between the thrust Lewisian gneiss and the underlying piled-up sedimentary strata on Beinn Arnaboll, we proceed to show that all the Cambrian strata on the east side of Loch Eireboll between Heilim and Creag-na-Faolinn lie in a synclinal fold, and have been driven westwards in front of the anticline of Lewisian gneiss along the Arnaboll thrust-plane. (Fig. 21.)

About a mile south of Heilim Pier, a promontory named An t-Sron forms the western headland of Camas an Duin, where a complete sequence can be traced from the pipe-rock to the Eilean Dubh dolomites and limestone as represented in the vertical table already given. (Chapter XXIV.) The hill-slope east of the promontory towards Bealach Mhairi presents a descending section from the highest sub-zone of the pipe-rock to the basal pebbly grit resting unconformably on the gneiss.

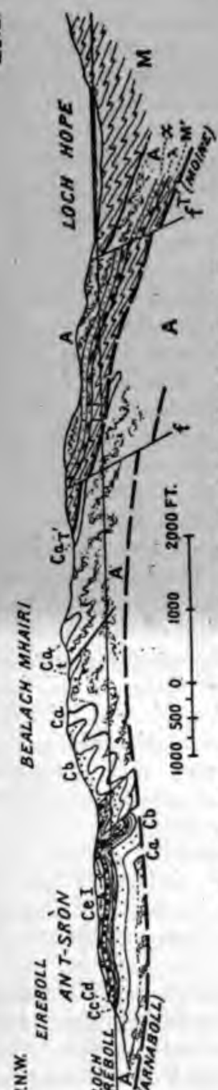

Fig. 21.—Section from An t-Sron by Bealach Mhairi to Loch Hope.

A. Lewisian Gneiss. Ca. Basal Quartzite (Cambrian). Cb. Pipe-rock. Cc. Fucoid-beds. Cd. Serpulite-grit. Ce I. Limestone (Ghrudaidh group). M'. Mylonised Rocks, Green Schists and Phyllites. M. Moine-schists. x. Quartz-schist. ℓ. Marble. T. Arnaboll-thrust. T'. Moine-thrust. t. Minor-thrust. f. Faults.

This section has figured largely in the literature bearing on the order of succession of the rocks in the North-West Highlands, for while Murchison maintained that it proved the existence of an upper quartzite, Nicol contended that the evidence confirmed his belief that the lower quartzite was brought up to the east by means of folding. The horizontal section given by Nicol* correctly represents, in broad outline, the sequence and relations of the Cambrian strata at Camas-an-Duin. He clearly saw that, in Camas Bay, where the pipe-rock dips eastwards apparently below the igneous mass of the hill (Lewisian gneiss) the openings of the annelid-tubes and the ripple-marks are there on "the lower faces, showing that there has been a complete reversal of the strata."† While accurately interpreting the sequence and relations of the Cambrian sediments at this locality, he regarded the Lewisian gneiss as intrusive granulite throwing off the strata on each side of the hill and involving large fragments of the mica-slate to the east. Hence he inferred that the mica-slate is the lower and older rock.

Subsequently, in 1883, Professor Lapworth described this section in detail, confirming Nicol's conclusions regarding the sequence of the sediments.‡ He added certain evidence of great

* *Quart. Journ. Geol. Soc.*, vol. xvii., p. 88, fig. 3.
† *Ibid.*, p. 89.
‡ "The Secret of the Highlands." *Geol. Mag.*, 1883, p. 126.

moment, viz., that on the eastern margin of the quartzite there rises from beneath the lower division of the arenaceous series the thin basal conglomerate, with its quartz pebbles and fragments of coloured shales. He further showed that this conglomerate rests on the highly crystalline or so-called "igneous rock" of the Sutherland gneiss, on the platform above the ridge (Bealach Mhairi), where a narrow island of quartzite is surrounded by the crystalline "igneous rock," and is separated from it by the basal conglomerate, the visible phenomena affording very clear evidence of a distinct unconformity between the two series. Professor Lapworth therefore inferred that this place affords a complete demonstration of the identity of the so-called lower and upper quartzites, and proves that the lower quartzite (and of necessity the whole of the fossil-bearing series) is of newer age than the "igneous rock" of the Sutherland gneiss.

These conclusions were independently confirmed by Dr. Callaway, who further pointed out the evidence for a small reversed fault in the bay near the Pictish Tower east of An t-Sron.*

On referring to Fig. 21, it will be seen that, for about one-third of a mile between An t-Sron and the Pictish Tower, south of Camas an Duin, the strata are arranged in a gentle compound anticline, the lowest members being the highest beds of the pipe-rock Cb), followed by the various sub-zones of the fucoid-shales (Cc). About 200 yards south-west of the promontory the soft cream-coloured shale appears at the top of the zone, from which, as already stated, fragments of *Olenellus* were obtained. Southwards along the shore the *Salterella-* (serpulite-) grit (Cd) follows in natural order, succeeded by the sub-divisions of the Ghrudaidh dolomites (Ce I.) and by the members of the Eilean Dhub group (Ce II. in Fig. 22). On the east side of the compound anticline, near the old Pictish Tower, the lowest beds of the Ghrudaidh dolomites are cut off by a reversed fault (shown in Fig. 21), which brings up the fucoid-shales, arranged in a double syncline, each fold containing a small outlier of serpulite-grit. Eastwards the latter sub-zone is brought into contact with the pipe-rock by a small thrust, and as the observer ascends the hill-slope to the east he encounters both divisions of the quartzite, usually in inverted order and arranged in one or more isoclinal folds. At the junction with the Lewisian gneiss the false-bedded grits with the thin basal conglomerate dip to the E.S.E. in inverted order at 80°. About 200 yards to the east a small patch of basal quartzite lies in a fold in the gneiss, which is truncated on the south-east side by a reversed fault (Fig. 21); and about 30 yards further up the hill the outlier (Ca) described by previous observers appears, measuring 700 yards in length and 150 yards in breadth. In this outlier the strata, belonging wholly to the lower division of the arenaceous series and including the basal fine conglomerate, are isoclinally

* *Quart. Jour. Geol. Soc.*, vol. xxxix., p. 398 *et seq.*

folded and dip to the E.S.E. The adjacent Lewisian rocks consist of crushed hornblendic gneiss with veins of granite and pegmatite. Eastwards strips of highly-sheared and rolled-out quartzite may be observed close to the Moine thrust-plane which may probably be lenticles of the basal quartzite.

The mass of Lewisian rocks on Bealach Mhairi is merely the southward prolongation of that on Beinn Arnaboll, for one can walk continuously on the old Lewisian platform for a distance of a mile and a half from the one point to the other. (Sheet 114.) Further, the unconformable junction between the gneiss and the Cambrian strata can be traced for about a mile on one line along the west slope of Bealach Mhairi north to Druim na Teanga, where both the gneiss and the inverted quartzites come in contact with the piled-up fucoid-beds, serpulite-grit, and dolomites to the north and east. Again, a patch of the basal quartzites resting unconformably on the Lewisian gneiss is found above the Arnaboll thrust-plane on the west face of Beinn Arnaboll, as shown in Fig. 20.

The difficulty in explaining these complicated relations at once disappears, if we follow the outcrop of the Arnaboll thrust-plane. Owing partly to its gentle inclination and partly to folding and denudation, its outcrop forms a remarkably sinuous line. It is clearly seen on the east and north slopes of Beinn Arnaboll, whence it can be followed round the west face of the hill, descending into the hollow on the west, then bending back on itself, winding round the north margin of the quartzites on Drum Teanga and entering Loch Eireboll in Heilim Bay. From that point it traverses the floor of the loch southwards and reappears at the base of Creag-na-Faoilinn. This structure accounts for the inversion of the quartzites east of Camas an Duin and for the occurrence of the lower groups of dolomites at Eireboll House, which will now be described.

As shown in Fig. 22, the Cambrian strata from their base up to the Eilean Dubh limestone rest undisturbed on the floor of Lewisian gneiss along the west side of Loch Eireboll.

But on the east side of the loch the structure at once becomes greatly complicated. The broad features at An t-Sron are continued southwards to the low plateau at Eireboll House, with this modification that the folds in the latter area are now represented in the two lowest groups of the Calcareous series (Ce I., II.). South of An t-Sron a passage is traceable upwards from the *Olenellus* zone to the dolomites of the Ghrudaidh and Eilean Dubh groups, which cover the low ground bordering the loch for two and a half miles to a point beyond Rudh Ard Badanach and within a mile of the base of Creag-na-Faoilinn. The dolomites are arranged in a gentle compound anticline, the Eilean Dubh beds (Ce II. in Fig. 22) extending inland from the shore to near the high road beyond Eireboll House, where the underlying dolomites of the Ghrudaidh sub-division come to the surface and form a sharp syncline, followed by the serpulite-grit, fucoid-beds, and pipe-rock, sometimes in inverted order. Here

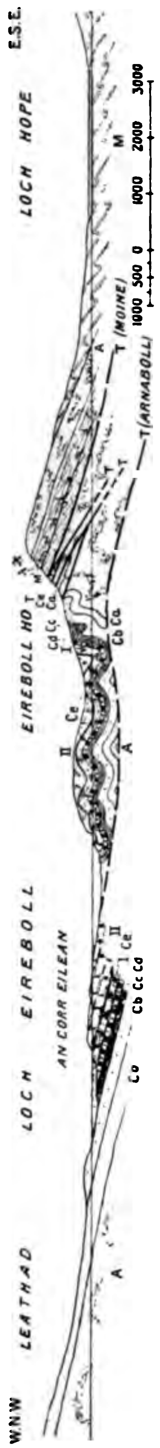

FIG. 22.—Section from Leathad by An Corr Eilean and Eireboll House to Loch Hope.

A. Lewisian Gneiss. Ca. Basal Quartzite (Cambrian). Cb. Pipe-rock. Cc. Fucoid-beds. Cd. Serpulite-grit. Ce. Limestone. Ce I. Dolomite (Ghrudaidh group). Ce II. Dolomite (Eilean Dubh group). M'. Mylonised Rocks, Green Schists, and Phyllites. M. Moine-schists. x. Quartz-schists. λ. Marble. T. Arnaboll-thrust. T'. Moine-thrust.

neither the basal quartzites nor the unconformable junction with the Lewisian gneiss are exposed, as the section is interrupted by a thrust which brings forward highly-sheared materials. But the conclusion is obvious that the Cambrian strata on either side of Eireboll House are the southern prolongations of those which at An t-Sron and in Camas-an-Duin overlie the Arnaboll thrust-plane. Hence this line of displacement is represented in Fig. 22 as lying beneath the thrust limestones at Eireboll and coming to the surface between An Corr Eilean and the eastern shore of the loch. This small island about a mile W.S.W. of An t-Sron is composed mainly of dolomites of the Eilean Dubh group, dipping to the E.S.E. at angles varying from 10° to 15°. From the absence of any indications of reversed faulting or other disturbance, it is highly probable that the limestones here are in natural sequence with the undisturbed Cambrian strata on the west side of the loch.

The sharp syncline in the limestone east of Eireboll House and the inversion of the underlying Cambrian strata were noted by Nicol and represented in his section of that area,* and his observations were subsequently confirmed by Dr. Callaway. Nicol further noted the thinning-out southwards of the igneous rock of Arnaboll Hill (Lewisian gneiss) and the occurrence of mica- and talc-slates with innumerable fine threads or lines of igneous material, in association with the quartzites.

Continuing the section east of Eireboll House, we find, on the west slope of Meall a' Bhaid Tharsuinn, that the inverted pipe-rock is succeeded by highly-sheared gneiss, the two being separated by a well-marked thrust. Along this declivity and

* *Quart. Jour. Geol. Soc.*, vol. xvii., p. 92, Fig. 5.

about the same level strips of flaser gneiss are interleaved with bands of mylonised quartzite, the planes of schistosity being parallel to the powerful thrust-planes. That these siliceous zones are in all probability deformed basal quartzites of the Cambrian sequence is supported by the fact that in this line of section, about the 700-feet contour line, a lenticle of sheared dark-blue limestone with black chert nodules appears, which may probably be a portion of the Balnakiel group of the Durness dolomites. On the one-inch Sheet 114, these strips of sheared gneiss, quartzite, and limestone are represented as occurring in the materials overlying the Moine thrust-plane, but it is not improbable that their appearance is due to intermediate thrusts in advance of that great line of disruption, as shown in section. (Fig. 22.)

(c) *From the Hope River to Ceann Geal Mor (Whitten Head).*

This tract of ground west of the Moine thrust is occupied partly by Cambrian strata, chiefly quartzites, repeated by faults and folds, as in the area round Beinn Heilim, and partly by displaced masses of Lewisian gneiss. The outcrop of the Arnaboll thrust-plane, which descends the east slope of Beinn Arnaboll to Loch Hope, is then shifted northwards to Inverhope by a fault which runs along the lower part of the lake. Thence, the thrust-plane, overlain by a mass of Lewisian rocks, can be followed north to Cnoc na Uilt Tharsuinn, where it is overlapped by the Moine thrust. The two patches of gneiss shown on Sheet 114 near the eastern headland of Loch Eireboll—one S.S.E. of Freasgeal and the other forming Cnoc Ard an Tionail—are probably outliers of the materials above the Arnaboll thrust-plane, which have been let down to the west by normal faults (Fig. 23). The outcrop of this line of displacement beneath the Cnoc Ard an Tionail mass is well seen on the top of the cliff at Whitten Head, Ceann Geal Mor, and on Mol Mohr. The piled-up strata, which there underlie the plane, consist of basal quartzites, which have been driven on to the pipe-rock in the bay termed Mol Mohr. Southwards in Geodh' a' Bhathaich the fucoid-shales and the uppermost zone of the arenaceous series are repeated by minor reversed faults.

The unconformable junction of the lower division of the quartzite with the Lewisian gneiss is displayed on the cliff a quarter of a mile south-west of Ceann Geal Mor, where it dips to the west at 80°, with the thin pebbly conglomerate at its base. On the sea-stack to the north it is inclined to the north-east. Another exposure is met with in a small stream draining Loch na Beiste, about a mile and a half south of the Whitten Head, where the basement breccia or conglomerate is inverted and dips to the E.S.E. at 45°. The triangular mass of Lewisian rocks lying to the east of this unconformable strip of basal quartzite occupies the lofty sea-cliff for about a mile east of Ceann Geal Mor, where the rocks consist of crushed hornblendic

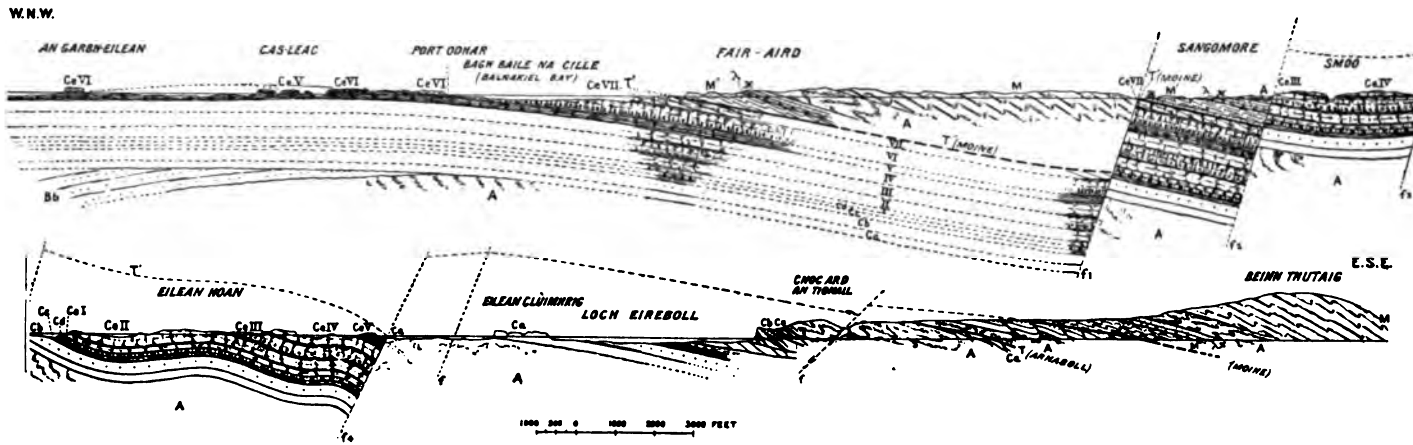

FIG. 23.—Section from An Garbh Eilean by Fair-aird Head and Eilean Hoan to Cnoc Ard an Tionail and Beinn Thutaig.

A. Lewisian Gneiss. Bb. Torridon Sandstone. Ca. Basal Quartzite (Cambrian). Cb. Pipe-rock. Cc. Fucoid-beds.
Cd. Serpulite-grit. Ce. I.—Ce VII. Sub-divisions of Cambrian Dolomite and Limestone.
M′. Mylonised Rocks, Green Schists, and Phyllites. M. Moine-schists. x. Quartz-schist. λ. Marble.
T. Arnaboll-thrust. T′. Moine-thrust. f. Faults.

gneiss traversed by veins of granite and pegmatite. Along the eastern margin of this mass it is overlain unconformably on the top of the cliff by a thin patch of basal quartzites, which is truncated by the Moine thrust.

The structures just described near Ceann Geal Mor are represented in the accompanying section (Fig. 23), which has been prepared to show the relations of the strata north of the Durness basin to those in the north-east part of the Eireboll region. In the double system of normal faults which have been alluded to as traversing the Durness area, one set trends north-east, while the other, of later date, cuts these nearly at right angles. By means of one of the later north-west dislocations, which truncates the Durness basin along its northern margin, the dolomites of the Croisaphuil zone (Ce VI.) have been thrown five miles to the north-west, as far as An Garbh-eilean (Sheet 114). This displacement has likewise shifted the outcrop of the Moine thrust-plane from Sango Bay to the west of Fair-aird Head. Though not exposed at the surface, the position of the thrust-plane must be close to the western base of the headland, as the islets in the north part of Balnakiel Bay are composed of Cambrian dolomite and limestone which underlie that plane. The shore-section from Fair-aird south-east to Seanachaisteal (Bishop's Castle) displays a fine development of the Eastern schists, including the platy mylonised rocks, frilled schists, sheared gneiss, and siliceous Moine-schists (M', λ, x, A, M, in Fig. 23), which were correctly correlated by Murchison and Nicol with the schists in the neighbourhood of Beinn Thutaig, east of Loch Eireboll.

(d) *From the Head of Loch Eireboll to Loch More.*

At the head of Loch Eireboll the conspicuous escarpment of Creag na Faolinn on the east side of the valley, composed partly of a slice of Lewisian gneiss about 600 feet thick, presents with great clearness the tectonic relations of the rocks. On the west side of Strath Beag, between Crann Stacach and Polla, the thin cake of Cambrian quartzite having been partly removed (Ca, Cb), the platform of Lewisian gneiss (A) has been laid bare, presenting there its normal lithological characters and its usual north-west strike. At the head of Loch Eireboll, to the west of the outlet of the Strath Beag River, the false-bedded grits and pipe-rock follow in normal order, but in the centre of the valley the evidence is concealed by alluvial and morainic deposits. Crossing the river to the south-east base of the crag, we find lenticular masses of the top zone of the pipe-rock, fucoid-beds, and serpulite-grit (Cb, Cc, Cd) repeated by reversed faults, until they are abruptly cut off by the Arnaboll thrust, which brings forward a mass of the basal quartzites (Ca) resting unconformably on the Lewisian gneiss (A). The piled-up members of the Middle Series, and especially the *Olenellus* zone, can be followed

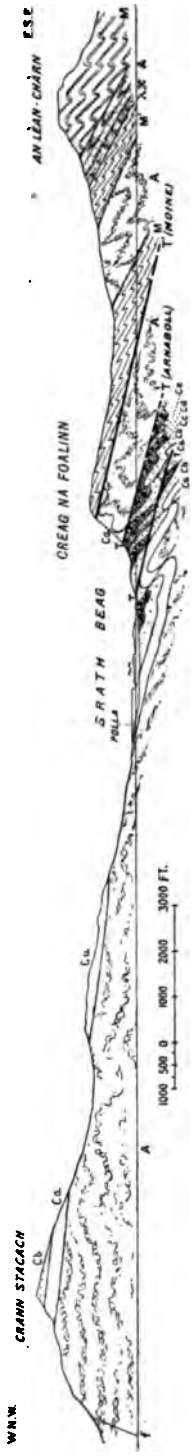

FIG. 24.—Section from Crann Stacach across Srath Beag and Creag na Faolinn to An Léan-chárn.

A. Lewisian Gneiss. Ca. Basal Quartzite (Cambrian). Cb. Pipe-rock. Cc. Fucoid-beds. Cd. Serpulite-grit. Ce. Limestone. M'. Mylonised Rocks, Green Schists, and Phyllites. M. Moine-schists. x. Quartz-schist. λ. Marble. T. Thrusts. T'. Moine-thrust. f. Fault. ⌒ Alluvium.

round the base of the crag to near the bend in the high road. There they are directly overridden by the Lewisian rocks, which form the northern half of the crag, and consist of hornblendic gneiss with veins of pink granite and pegmatite. Though somewhat crushed, these rocks closely resemble Lewisian types seen to the west. The unconformability of the basal quartzites on the gneiss above the Arnaboll thrust-plane can be traced up to the top of the crag, where both the gneiss and quartzites are truncated by the Moine thrust. (T' in Fig. 24.) Special interest attaches to the exposure here of this upper disruption-line, for on the northern slope of the hill the plane of the Moine thrust, composed of sheared gneiss, is laid bare and shows its lines of stretching, trending E.S.E. and W.N.W. Immediately above the plane, green, platy, fissile mylonitic rocks are followed by a great development of epidotic flaser-gneiss and pegmatite, with a fine parallel banded structure containing knots and lenticles, in which the original lithological characters have not been effaced. The planes of schistosity in these deformed materials dip generally to the E.S.E.—that is, more or less parallel with the plane of the Moine thrust. Eastwards a considerable mass of deformed gneiss, in which the original structures are well preserved, is followed by a series of the Eastern or Moine schists.

A still more conspicuous example of a lenticular mass of displaced Lewisian rocks overlying the Arnaboll thrust plane occurs about a mile further up Strath Beag on the east side of the valley at Creag Earail. Measuring about a mile and a half in length and three-quarters of a mile in breadth, it rises from the 100-

feet level to a height of over 1000 feet. It consists mainly of green hornblendic gneiss with veins of pink granite and pegmatite. A noteworthy feature is the occurrence of the north-west strike throughout this mass, though signs of crushing are discernible and numerous veins of epidosite have been developed. The tectonic structure precisely resembles what is seen at Creag na Faoilinn, for the Arnaboll thrust can be traced round the base of the crag, with the piled-up pipe-rock, fucoid-beds, and serpulite-grit lying beneath that plane, while the crag is capped with an outlier of the sheared rocks above the Moine thrust. The outcrop of this great displacement is to be seen further east. A striking characteristic of the mylonised materials accompanying this dislocation is the presence of a zone of shattery quartz-schist immediately above the thrust-plane.

The mountainous region stretching southwards by Foinne-Bheinn and Beinn Arcuil to Loch More furnishes two important links in the chain of evidence relating to the tectonics of this northern region. In the first place, it demonstrates in the clearest manner that the piled-up Cambrian strata in advance of or west of the Arnaboll thrust have themselves been driven westwards along a plane or "sole," separating the displaced materials from the underlying undisturbed strata. In the ground above described the proofs of this structure are concealed under the waters of Loch Eireboll. In the second place, we learn that the first thrust-plane or "sole," along which the heaped-up Cambrian strata have been driven, appears here on a lower level than in the tract north of Heilim—viz., on the horizon of the lower division of the quartzites. Hence the zones, repeated by reversed faults above this plane or "sole," consist chiefly of a small part of the basal quartzites (Ca), all the sub-divisions of the pipe-rock, together with the fucoid-beds and serpulite-grit where these have escaped denudation.

Fig. 25, which gives a section of the ground from Fionne-Bheinn to Sabhal Mor—a distance of five and a half miles—supplies a typical illustration of the structure of the whole region from Strath Beag to Loch More as regards the belt to the west of the great disruption-lines. On Ceann Mor (2980 feet—the highest peak of Foinne-Bheinn—the undisturbed quartzites appear in force, including the lower division (Ca), about 300 feet thick, and the lower zones of the pipe-rock (Cb), 150 feet, inclined to the south-east at about 15°. Following the ridge towards Creag Dionard and Plat Reidh, the observer finds that the members of the arenaceous series are suddenly tilted at higher angles, and that, for a long distance, the sub-zones are constantly repeated in the same definite order by reversed faults.

In the unravelling of this type of structure between Strath Beag and Loch More, the sub-divisions of the pipe-rock, and particularly Sub-zone III., with the "trumpet" pipes and the band of quartzite containing *Salterella* associated with it, have been found to be of great service. The minor displacements are clearly exhibited in many cliff sections, notably in the great

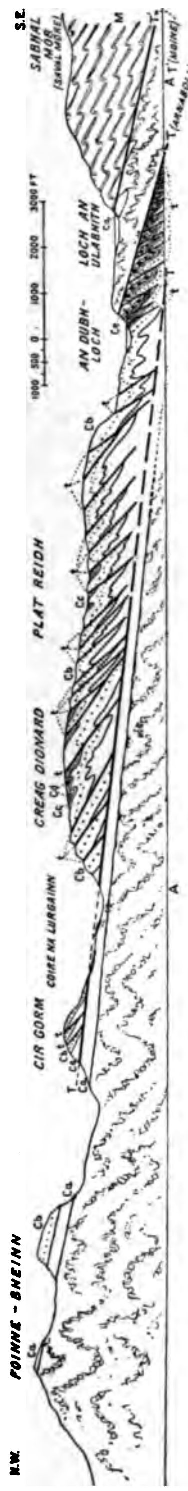

FIG. 25.—Section from Foinne-Bheinn by the Plat Reidh and An Dubh-Loch to Sabhal Mòr.
A. Lewisian Gneiss. Ca. Basal Quartzite (Cambrian). Cb. Pipe-rock. Cc. Fucoid-beds. Cd. Serpulite-grit.
Ce. Limestone. M. Eastern Schists. T. Thrusts. T'. Moine-thrust. t. Minor-thrusts.

precipices overlooking Strath Dionard (Sheet 114), in the lofty crag above Loch na Tuaidh on the north-east side of Beinn Arkle (or Arcuil), and on the ridge between Strath Dionard and Strath Beag, where the relation of the reversed faults to the undisturbed strata beneath is apparent. A careful examination of the last of these sections shows these minor displacements to be branches of an underlying thrust, whose plane approximately coincides with the bedding planes of the basal quartzites. The outcrop of this major thrust-plane follows a very sinuous course. Ascending the hill-slope west of Strath Beag, it crosses the ridge north of Conamheall, thence to the foot of Loch Dionard, and across Foinne-Bheinn to Loch na Tuaidh. From that point it curves round the northern face of Beinn Arkle, thence south-eastwards by Allt a Chuirn above Lone, till it is concealed under a covering of peat and turf. Its position near the top of the basal quartzites is remarkably constant, and, as might be expected, it has given rise to a prominent structural feature which not only interrupts the continuity of the quartzites, but has influenced the denuding agents in their operations. At certain localities the piled-up strata lying at an oblique angle to the plane have been stripped off and the surface of the plane of disruption has been laid bare—as, for example, in the deep corrie of Am Bathaich, on the south side of Beinn Arkle, and on the floor of Coire na Lurgainn between Cir Gorm and Creag Dionard. (Fig. 25.)

Immediately above this major thrust-plane or "sole," thin wedges of basal quartzite appear in the piled-up materials, but on the top of the Plat Reidh (Fig. 25), on the ridge of Conamheall, and on Beinn Arkle the pipe-rock alone is exposed with strips of Fucoid-beds at intervals. The outcrops of the reversed faults on these lofty plateaux are usually indicated by long narrow hollows occupied by the remnants of the dolomitic shales.

At certain localities this system of reversed faults is accompanied by folding—as, for example, on the face of Creag Dionard (Fig. 25), which becomes more pronounced eastwards near the Arnaboll or Moine thrusts. It is worthy of note that by this system of reversed faults and folds the quartzites on the Plat Reidh and on Ben Arcuil are reduplicated till they appear to be about two and a half times their normal thickness.

Eastwards from the Plat Reidh at An Dubh Loch (Fig. 25) the piled-up Cambrian strata are truncated by the Arnaboll thrust, which has brought forward a mass of Lewisian gneiss. Beneath this thrust-plane the fucoid-beds, serpulite-grit, and occasionally the basal dolomite, with an imbricate structure similar to that at Heilim (Fig. 20), are exposed, particularly on the south and west sides of An Dubh Loch. It is not improbable that the comparatively even surface of the Plat Reidh may be due to the former westward continuation of the Arnaboll thrust at a comparatively small height above its present level. The displaced gneiss overlying this plane, which is traceable for two miles from Loch an Ulabhith to Loch Fir Dhurinnis, is more deformed than the mass occupying the same relative position on Creag Earail in Strath Beag, already described. The original strike has been nearly obliterated, and the hornblendic rocks, associated with much pink pegmatite, are traversed by numerous veins of epidorite.

East of these displaced Lewisian rocks lies the Moine thrust, whose outcrop in this region usually gives rise to a prominent feature in the landscape. Here it appears at the base of a steep slope of green schist, in which the foliation planes dip south-eastwards at low angles. First in order above the "sole" come green platy and frilled schists, the latter being highly crumpled, and forming a well-marked zone on the west face of Meall a' Chuirn. These are succeeded by the normal siliceous granulitic schists, which have been traced southwards from the ridge east of Eireboll.

One final feature regarding the tectonics of this northern district remains to be noted, in the behaviour of the Moine thrust relatively to the underlying strata, when followed along the strike southwards from the Eireboll region. Evidence has been adduced to show the irregular distribution of the masses of Lewisian gneiss above the Arnaboll thrust-plane, a feature which was noted by previous observers. These masses appear as narrow belts or lenticles, which are overlapped by the materials above the Moine thrust-plane, pointing to a complete discordance between the two. Hence we find, at various localities between Loch Eireboll and Loch More, that the Eastern schists, driven westwards by the Moine disruption, are frequently placed directly above the displaced Cambrian strata, both having a common dip in a south-easterly direction.

CHAPTER XXXIV.

GEOLOGICAL STRUCTURE OF THE GROUND BETWEEN LOCH MORE AND LOCH GLENCOUL.*

This tract of less elevated ground comprised in Sheets 107 and 108 of the map, affords many striking developments of the characteristic tectonic features of the North-West Highlands. These will be most conveniently illustrated by a series of transverse sections.

At the north end of the district a striking contrast is observable between the two sides of Loch More. On the south-west side the higher slopes of thrust Cambrian rock are composed to a large extent of fucoid-shale, serpulite-grit, and limestone, but those on the north-east side consist of quartzite, which there rises higher and covers a much larger surface. On the north-east side, also, the Cambrian rocks extend a mile further to the south-east than on the opposite side. The quartzite at the foot of Loch More is partly obscured, but does not seem appreciably displaced by a fault that runs up the loch. But a W.N.W. fault, hading and throwing down to south-west, is seen in Strath an Staca, and if continued in an E.S.E. direction it would trend along the loch. The contrast here referred to may perhaps be due to some obscure thrust hidden in the loch.

At the north-west end of the section shown in Fig. 26, the Lewisian gneiss (A) is covered unconformably by the quartzite (Ca, Cb), which has a gentle dip towards E.S.E. These rocks retain their original relations to each other. But immediately above them come masses of Cambrian rock which have been moved from the E.S.E., and disturbed by many thrusts and folds. It will be seen that in the south-eastern half of the section a small inlier of the gneiss emerges from beneath a mass of thrust and folded quartzite, and is itself folded, so that its north-western side is reversed, and the quartzite (Ca) appears to dip below the gneiss. The basal conglomerate of the quartzite, however, is exposed, showing that the junction of the two rocks is an unconformable one. This gneiss and the Cambrian rocks overlying it probably rest on the Glencoul thrust-plane, on which the thick masses of gneiss have been driven forward which appear above the unthrust quartzite at Loch Glendhu and Loch Glencoul. A little south of the line of

* By C. T. Clough.

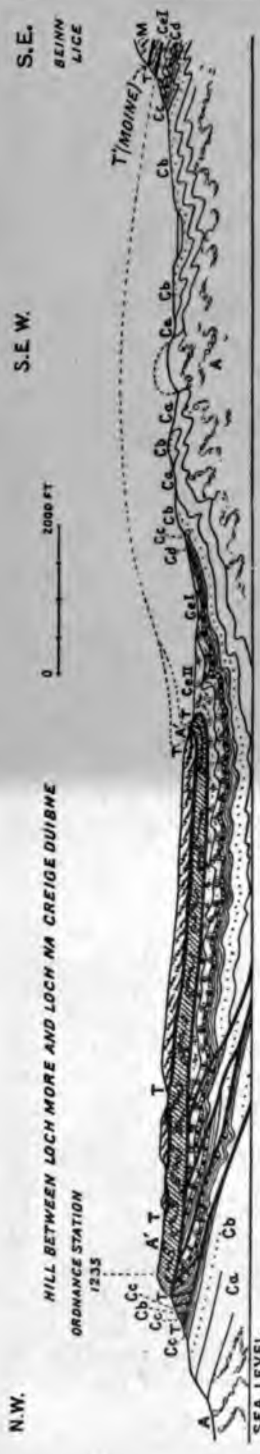

FIG. 26.—Section from half a mile west of Lochmore Lodge to near Beinn Lice.

A. Lewisian Gneiss. A'. Granitic Gneiss. Ca. Basal Quartzite (Cambrian). Cb. Pipe-rock. Cc. Fucoid-beds. Cd. Serpulite grit. Ce I. Ghrudaidh group. Ce II. Eilean Dubh group. M. Eastern Schists. T. Thrusts. T'. Moine-thrust.

section this thrust is distinguished from the others by these overlying masses of gneiss, but further north, at Loch na Creige Duibhe, the gneiss on the thrust is covered unconformably by the quartzite and other Cambrian rocks, and the beds on either side of it are of much the same character, so that it becomes uncertain which of the thrusts on the north side of the loch represents the Glencoul thrust.

Over the thrust Cambrian strata lie several other higher masses of rock, which have perhaps been carried from much greater distances. The lowest mass is chiefly of Lewisian granitic gneiss (A′), the next is a mylonised rock, and the third Moine-schist. The mylonised rock forms several very distinct outliers in, and near, the north-west half of the section, but the Moine-schist (M) only occurs near the south-east end. We shall speak further of these higher masses after completing the description of the lower.

At the north-west end of the section the boundary between the basal quartzite (Ca) and the pipe-rock (Cb) appears to be undisturbed, but before the serpulite-grit is reached a low-angled thrust or sole intervenes, on which are piled up stripes of quartzite and fucoid-shale. On the north-east side of the line of section some of the minor thrusts have been folded, and higher thrusts occasionally override lower ones. About a quarter of a mile south of the Lochmore shepherd's house the Cambrian rocks are found on the south side of some of the granitic gneiss and at a much higher level than to the west. Perhaps this is owing to a fold of slightly later date than the thrust on which these rocks were brought forward. The Cambrian rocks in the centre and near the south-east end of the section, which overlie the gneiss inlier, and which are supposed to be on the Glencoul thrust, appear to be disturbed by fewer thrusts than those on the "sole" near the north-west end.

The pipe-rock forms in one place a folded outlier on the basal quartzite, on the south-east side of which the dip is reversed, the pipe-rock appearing to dip under the basal quartzite. A little further to the south-east the base of the quartzite (Ca) is seen with its conglomerate, containing pebbles of quartz two or three inches long. These strata dip under a thin banded hornblendic gneiss—part of the inlier of Lewisian gneiss already referred to. Beyond the inlier the basal quartzite and the pipe-rock appear in their natural position, but they are considerably folded.

The quartzite around the gneiss inlier forms a folded dome nearly a mile and a quarter long from north-west to south-east, and a mile broad. The general dip on all sides is directed away from the centre. On the north-east and south-west sides the strike runs nearly at right angles to the general strike of most of the thrusts and axes of fold belonging to the great post-Cambrian movements. A north-westerly strike also prevails in the Moine-schists on the north-east side of the dome, but does not appear in the unthrust quartzite. We conclude, therefore, that the north-west strike was probably developed while the thrust-movements were in progress.

In some of the bands of pipe-rock in the dome the pipes, which in the undeformed rock are perpendicular to the bedding, have been dragged into a diagonal position, the deformation being greatest in the zones in which there is some admixture of shaly material. About 1500 yards S.S.W. from the top of Beinn Lice the angle between the pipes and the bedding is in some bands not more than 45°, while in others it amounts to about 70°.

Near the south-east end of the section drift comes on again, but between the quartzite and the Moine-schist cream-coloured compact limestone, probably part of the Eilean Dubh division, makes its appearance. The limestone is divided into thin laminæ dipping 23°, in a direction 22° north of east, which display minute flakes of white mica on their surfaces, and stretching lines which run nearly east and west. The extent to which the limestone has been altered suggests either that it lies on some higher thrust than the quartzite, or that it has been altered by some agent besides dynamo-metamorphism. A small exposure of dioritic rock (2735), seen a little north-west of the limestone, may belong to a thin intrusive sheet within the limestone. This sheet possibly crosses the line of section, and may have caused part of the alteration. It is the most northerly of the thrust post-Cambrian intrusive rocks, and lies seven or eight miles further north than any similar unthrust intrusion.

The thrust gneiss overlying the Cambrian masses in the north-western half of the section (A′) mainly consists of a red granitic gneiss like those near Laxford, but closely intermixed with many pegmatites and some dark-grey crushed bands of uncertain nature. Owing to the brecciation which this gneiss has undergone, its pre-Torridonian foliation is rarely distinct for more than a few yards. To find in the unthrust area similar granitic gneisses we must go, not to the nearest unthrust gneiss in a W.N.W. direction, but to the sides of Loch Stack, some two or three miles to the north—chiefly on account of the difference between the strike of the large masses of unthrust gneiss and the direction of movement of the thrusts, seeing that the general trend of these movements lay 15° or 16° nearer east and west than the strike of the gneiss. It is quite possible that the granitic gneiss in the section may have been thrust forward from a distance of nine or ten miles.

The thrust which brings on the granitic gneiss has in most places a gentle E.S.E. inclination, but about 700 yards south of Lochmore Lodge it becomes vertical with an east and west strike. About 1000 yards south-east from the Lodge it inclines steeply to south-west. The change of direction, and the rise in level of the boundary of the gneiss observable about a quarter of a mile south of Lochmore shepherd's house, may possibly indicate a folding of the thrust-plane. On the south side of the gneiss we have suggested in the section that the thrusts may also be reversed by folding along axial planes inclining south-east, for in some exposures the dip is southerly, as if the limestone were lying over the mylonised rock.

Nearly three-quarters of a mile E.N.E. from the head of Loch na Creige Duibhe, and only a little distance north-east of the line of section, considerable areas of limestone dipping south-east are exposed. The limestone seems at first to lie within the mylonised rock, but it is so little altered that we at once recognise that the western part belongs to the Ghrudaidh and the eastern part to the Eilean Dubh sub-divisions. It is difficult to explain how the limestone can have escaped with so little alteration if it really lay in the mylonised rock; possibly it may be intercalated between this rock and the granitic gneiss. The mylonised rock, of a dark-grey colour, and finely laminated, forms a striking contrast with the granitic gneiss. Eight or nine outliers of it rest on, or partly on, the granitic gneiss, two of the most conspicuous of which are crossed by the line of section. The rock shows a sericitic lustre on the parallel shear-planes, and contains many small eye-shaped bits of red felspar, together with some larger red masses, some as much as several yards long and several feet broad. Some of the masses seem to be composed of mylonised pegmatite, but others may have been derived from a granitic gneiss like that below. The shear-planes of the grey rock are much puckered, but their general dip is E.S.E. or south-east, and frequently at rather high angles. About 350 yards north-east of the mouth of the burn at the head of Loch na Creige Duibhe the thrust-plane between the grey rock and the granite gneiss is distinct, and it is here observable that the laminæ in the grey rock sometimes dip more steeply than the plane. The stretching lines in the mylonised rock run slightly north of west, a direction about 20° nearer east and west than that of the dip of the planes which they traverse. On the hill three-quarters of a mile south-west from Lochmore shepherd's house they are indicated by trains of small granules of epidote.

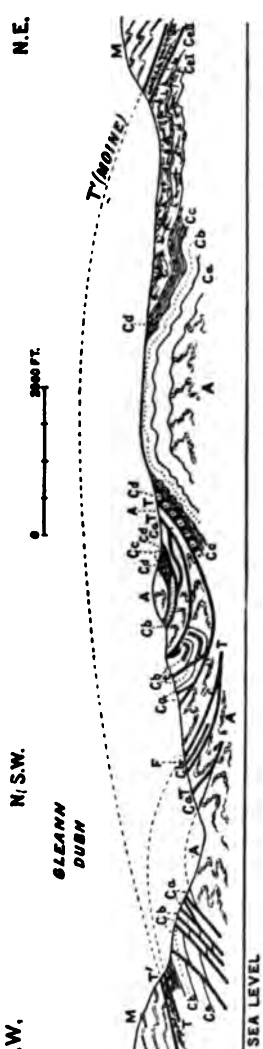

FIG. 27.—Section from the upper part of Glendhu to a point three-quarters of a mile S.S.E. from Beinn Lice.

A. Lewisian Gneiss. Ca. Basal Quartzite (Cambrian). Cb. Pipe-rock. Cc. Fucoid-beds. Cd. Serpulite-grit. Ce I. Ghrudaidh group. Ce II. Eilean Dubh group. M. Eastern Schists. F. Porphyrite sill. T. Thrusts. T'. Moine-thrust. t. Minor thrust.

It is uncertain what the rock was from which the grey mylonised rock has been chiefly formed, but it seems to contain, as already indicated, some pieces which may be mylonised granitic gneiss. On the north-east side of the line of section it is difficult to draw a line between this mylonised rock and the holo-crystalline Moine-schists of Beinn Lice.

The section (Fig. 27), in a general N.E. direction, crosses a tract where many of the rocks and thrusts have a north-westerly strike, and have been folded along axes which are nearly at right angles to the general direction of movement of the post-Cambrian thrusts. This north-westerly strike is found not only in many of the Cambrian masses, but also in the Moine-schists. All the Cambrian and Lewisian rocks have no doubt been covered by an arch of Moine-schist (indicated by the dotted line in Fig. 27), but the upper and central parts of the arch have been denuded so as to expose the rocks below the schist for a mile or more further east than they can be seen on either side of the arch.

Below the Moine-schist (M) and a band of mylonised rock which often underlies it, a large mass of Cambrian and Lewisian rocks, confused with thrusts, reposes on the Glencoul thrust-plane. The north-eastern part of this mass forms the great dome above referred to in the description of Fig. 26. The south-western part is so much disturbed by thrusts that its structure is difficult to make out, but probably the greater part, if not all, of it lies on thrusts which override the dome. None of these thrusts, however, are seen between the dome and the Moine-schists at the north-eastern end of the section, nor are they so numerous at the south-western end as they are a little further towards the north-east, as shown in the figure. But for the folding along north-west axes, and the denudation of the Moine arch, the higher masses now laid bare might never have been exposed. The north-eastern end of the section, and more than half of the Cambrian dome, are so covered by drift that many of the rocks which we suppose to occur in this area are not seen for considerable distances from the line of section. We shall describe first the Cambrian and Lewisian rocks to the south-west of the dome, and then the mylonised rocks and Moine-schist.

The rock on the south-west side of the serpulite-grit (Cd) in the south-west limb of the dome is gneiss, beyond which lies a band of basal quartzite (Ca), probably separated from the gneiss by a thrust of no great magnitude. In an adjacent exposure the basal quartzite can be seen lying unconformably on the gneiss, which contains patches of sheared agalmatolite. On the south-western side of the basal quartzite, however, a thrust must intervene, for there the serpulite-grit (Cd) and fucoid-shale (Cc) appear, the latter converted in places into a lustrous schist. Beyond these Cambrian formations the Lewisian gneiss comes on again (A). Its boundary, which can be easily traced, is found to be twisted into a syncline with north-west axis. On the north-east side of Loch Strath nan Asinnteach, the same gneiss is overlain unconformably by the basal quartzite, and a mass of gneiss and quartzite seems to rest on a still higher thrust-plane. A junction of the quartzite and the gneiss mass which joins the gneiss at the top of the section is well seen about 300 yards east of the outlet of Loch Strath nan Asinnteach, but the two rocks have been so much sheared that the unconformability between them is to a large extent masked.

On the south-west side of the highest gneiss in the syncline more masses of gneiss and Cambrian strata appear to crop out than on the opposite side. Perhaps several of them lie on one thrust, like the piled-up stripes on the low-angled thrust or sole near the north-west end of the section in Fig. 26. The thrusts have sometimes brought rocks high in the original undisturbed sequence over others which are lower—for instance, the pipe-rock sometimes lies directly on the gneiss without the intervention of any basal quartzite. Some of the thrust masses of basal quartzite and pipe-rock include sheared intrusive sills, which cannot all be shown in the section. One sill generally appears a little above the base of the quartzite, and another a little above the base of the pipe-rock. Some of the rocks in these thrust masses have been greatly deformed. Thus, in a burn nearly a quarter of a mile south-west from the foot of Loch Strath nan Asinnteach, an exposure may be seen of basal quartzite in which some of the pebbles are two inches long though only ⅛-inch broad, and the long axes of all those on the same slab are parallel, generally trending about west 3° north, but sometimes west 24° south. Some of the felspar pebbles have been repeatedly cracked almost at right angles to the long axes, and the cracks are filled with quartz. Further up the same burn the conglomerate at the base of the quartzite is represented by a thin streak of pale yellow sheared rock, perhaps formed chiefly from agalmatolite, which contains pebbles of quartz. The total thickness of the basal quartzite and of four thin sheared intrusive sheets which occur in it is here only about 30 or 40 feet.

In Gleann Dubh burn, about 700 yards below the outlet of Loch Strath nan Asinnteach, for a few feet above and below an exposure of a thin stripe of basal quartzite, the gneiss has been greatly sheared, especially the south-western portion of the mass, its chief planes being parallel to those in the quartzite. The exposure of gneiss shown at the south-west end of the section in Fig. 27, just under the Moine-schist, is part of this sheared mass. It is mixed with many thin stripes, from a few feet to some yards in length, of basal quartzite, at least nine of which can be seen in a space less than 170 yards long. The gneiss and quartzite are here so mixed, and have their chief planes so parallel, that they may be considered to form a new complex.

The Moine-schists (M) at the north-east end of the section are chiefly siliceous granulitic flagstones, folded into isoclines with both limbs dipping at gentle angles slightly to the north of east. The mylonised rock represented below the schist is not actually seen in the line of section, but it may be there concealed under drift.

The section (Fig. 28) is drawn through a tract in which the Glencoul thrust is very clear, and from which it can be traced for many miles to the south.* It is by this dislocation that the great masses of gneiss which form Beinn a' Bhutha, Beinn Aird da Loch, and Cnoc na Creige have been driven over the quartzite. Some of these masses are more than 1700 feet thick and at least several miles broad. This important displacement, known as the Glencoul thrust, is not that which has brought forward the granitic gneiss in the section shown in Fig. 26. At the head of Loch na Creige Duibhe the granitic gneiss has been thrust over Cambrian limestones, which rest, without much disturbance, upon the serpulite-grit, fucoid-shale, and quartzite on the north-

* It has been figured and described by Dr. Callaway. "The Age of the Newer Gneissic Rocks of the Northern Highlands." *Quart. Journ. Geol. Soc.*, vol. xxxix., p. 373.

eastern side of Beinn a' Bhutha. These Cambrian rocks below the thrust extend E.S.E. for more than a mile, and as they dip N.N.E. more steeply than the slope of the ground the mass of gneiss which lies unconformably below the quartzite soon appears towards W.S.W. This gneiss must, therefore, lie below the granitic gneiss, and the Glencoul thrust which has carried it forward must lie below the thrust which brought up the granitic gneiss.

FIG. 28.—Section across Loch Glendhu and the North-East Side of Beinn Aird da Loch.

A. Lewisian Gneiss. Ca. Basal Quartzite (Cambrian). Cb. Pipe-rock. Cc. Fucoid-beds. Cd. Serpulite-grit. Ce I. Ghrudaidh group. M. Eastern Schists. F. Porphyrite Sill. T. Thrusts. T'. Moine-thrust. t. Minor thrusts.

The Glencoul thrust may possibly lie directly in certain places on unthrust Cambrian rocks, but in other places a thrust mass of considerable thickness is interposed between it and the undisturbed quartzite. The intervening material, which consists mainly of thin stripes of Cambrian strata, often dipping steeply and separated from one another by steep minor thrusts sometimes rests on a low-angled thrust or sole which has nearly the same inclination as the Glencoul thrust. (Fig. 28.)

The mass of gneiss brought forward by the Glencoul thrust is covered at various places, besides the north-east side of Beinn a' Bhutha, by Cambrian strata which rest on it unconformably, and are frequently crossed by steep lines of rupture, probably formed while the mass was being thrust forward. But no displacements comparable in magnitude to the Glencoul thrust are met with until near the south-east end of the section, where, overlying the Cambrian rocks, sheared Lewisian gneiss and schist of the Moine series have been brought forward by different thrusts with gentle inclinations in an E.S.E. direction.

In the line of section followed in Fig. 28, the Glencoul thrust-plane is not actually exposed at the surface, but on the north side of Loch Glencoul it overlies fucoid-shale, and this horizon has perhaps often formed a plane of weakness along which the rupture has proceeded. Between Aird da Loch and the head of Loch Glencoul, a distance of about a mile and a half, the outcrop of the thrust-plane descends from about 700 feet to the sea-level, with a general inclination of about 7° in an E.S.E. direction. This slope is less than the average dip of the quartzite below, and, as for some distance on the north side of Loch Glencoul the thrust-plane is nearly flat or even inclines towards north-west, the mass of strata between the quartzite and the overlying gneiss increases in thickness towards the upper end of the inlet.

The gneiss (A) just above the Glencoul thrust-plane has been sheared and is crossed by bands of crushed gneiss parallel to the plane of movement. A little above that plane, however, the pre-Torridonian banding in the gneiss becomes quite distinct, and in many places can be seen to strike nearly at right angles to the thrust-plane. The Lewisian rocks here exposed differ lithologically from those in the unthrust area lying to the west of them. They contain many thick red pegmatites, which in the unthrust gneiss are rare. On the other hand, while basic dykes of pre-Torridonian age are numerous in the unthrust gneiss, they appear to be absent from the thrust gneiss beyond half a mile north from Glen Coul. In the unthrust gneiss the belt which in respect of pre-Torridonian features most resembles the thrust gneiss of this locality lies some miles further to the north.* The thrust gneiss and pegmatites of Beinn a' Bhutha and Beinn Aird da Loch are crossed and slightly faulted by many thin epidotic strings, having no general direction, and probably produced during the thrust-movements.

About a mile from the south-east end of the section in Fig. 28 the basal quartzite can be seen to rest on the thrust gneiss and to dip to the east. The boundary between the two rocks probably keeps along the original unconformable junction, for some of the pegmatites under the quartzite contain sheared agalmatolite—a material rarely found except near the old pre-Cambrian floor. Yet there has been enough of movement along the junction to produce parallel shear planes in the gneiss. On either side of the line of section a thin, somewhat sheared intrusion of porphyrite appears at, or near, the base of the quartzite. The pipe-rock succeeds the basal quartzite, but before we reach the top a line of compact crush (t), hading towards west in some places, brings on the gneiss again, covered unconformably by the basal quartzite dipping E.S.E. Another crush line (t) is soon crossed, and we then enter an area of gneiss rather more than

* The N.E. belt described in Ch. IX.

300 yards broad, at the further side of which a thin band of hornblende-porphyrite (2736) occupies a narrow depression, and clings to the base of the quartzite for a great distance (F). Higher up in the succession comes the pipe-rock in its natural position, followed by an obscure area which is probably underlain by thin stripes of fucoid-shale, serpulite-grit, and limestone, disturbed by occasional faults. Though not seen along the line of section, at least six of these faults break through the base of the basal quartzite, the porphyrite, or the pipe-rock, a little further to the north. They strike nearly north and south, and have a hade and downthrow towards the west. They closely resemble the lines of compact crush just referred to, and, like them, hade in the direction of downthrow—differing in this respect from the common thrusts—but, on the other hand, they twist more frequently and suddenly than most normal faults. They end in a northerly direction at a line of thrust which strikes W.N.W., and which emerges from below the great thrust that brings on the gneiss at the south-east end of the section. They not improbably form part of the series of dislocations produced during the thrust-movements.

The highest member of the Cambrian series here exposed is the Ghrudaidh limestone, which is seen under the gneiss and crumpled schist at the south-east end of the section. The gneiss overlying the limestone, which is a much-sheared part of the band shown at the south end of the section in Fig. 27, encloses many thin streaks of highly-sheared basal quartzite, as well as other siliceous streaks of more uncertain character. Near Lochain Feith an Leothaid some red mylonised stripes, which may have been formed from pegmatites, are nearly parallel to one another and to the chief shear-planes, so as to give the rock a flaggy appearance. The shear-planes are contorted and crossed by many almost horizontal fault-planes, which also cross the red stripes, and must have been formed after the rock was in a mylonised condition. Both the shear-planes and the limbs of fold are generally inclined to east or south-east—in the same direction as the chief planes in the quartzite a little further to the west. The schist above the mylonised gneiss contains many thin much-puckered siliceous stripes, and is part of the "Stack schist." A little further to the south-east a gradual change occurs in the lithological character of the rocks, which pass into less-crumpled granulitic schists like those on Beinn Lice.

In the ground traversed by the section in Fig. 29 the Glencoul Thrust is likewise strongly marked, but it is here overlain by another great thrust which, often with a hade to north-west, has carried forward a mass of gneiss, together with some quartzite lying unconformably upon it, as well as other Cambrian rocks, often separated from one another by minor thrusts. At the south-eastern end of the section two still higher thrusts are shown—perhaps continuations of the two at the south-east end of the section in Fig. 28. The lowest of these has carried forward a thin band of greatly-sheared rock—apparently Lewisian gneiss

—while the highest, or Moine Thrust (T′), has brought on a fine-grained puckered schist which contains many thin siliceous streaks, and which seems part of the band represented in Fig. 28.

Near the shore, and on the islands near the head of Loch Glencoul, the stripes of fucoid-shale and serpulite-grit become mixed in a south-easterly direction with Ghrudaidh limestone. This constant repetition of strata is due to steep thrusts rather than to folds, and from the sections on the sides of the loch it would seem that these steep stripes and thrusts have all been carried forward on a low-angled thrust or sole (T) of much the same character as that represented near the north-west end of the section in Fig. 26.

The Glencoul thrust-plane, on which the thick mass of gneiss exposed in the north-western half of the section has been driven forward, is seen on two islands and near the south side of the loch. For a few feet above it the rocks are often finely sheared along planes striking parallel to the thrust-plane, so that the old band-

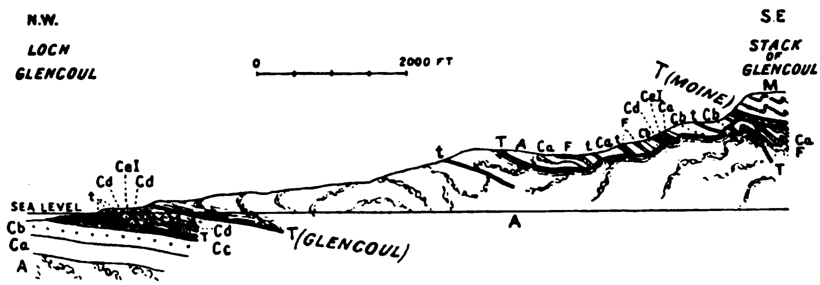

FIG. 29.—Section from Loch Glencoul to the Stack of Glencoul.*

A. Lewisian Gneiss. Ca. Basal Quartzite (Cambrian). Cb. Pipe-rock.
Cc. Fucoid-beds. Cd. Serpulite-grit. Ce I. Ghrudaidh group.
M. Eastern Schists. F. Intrusive Igneous Rocks. T. Thrusts.
T′. Moine-thrust. t. Minor thrusts.

ing of the gneiss cannot be recognised. Higher up, the gneiss contains many basic pre-Torridonian dykes, now generally in the condition of hornblende-schist, though dykes of the same chemical composition and age in the unthrust gneiss to the west are seldom foliated except near the edges, or along lines of special shearing. Many thick pegmatites appear in this displaced mass of gneiss and in the basic dykes, though such pegmatites are rare in the unthrust gneiss to the west. The unmoved gneiss that best corresponds with the thrust gneiss of Glencoul lies about six miles to the north. In most of the thrust gneiss the basic dykes trend towards W.N.W. as in the unthrust area; but to the west of Glencoul House, and to a less extent to the N.N.E. of Loch Coir' a' Bhaic, when the dykes come within a little distance of the Glencoul thrust they are twisted nearly into parallelism with it. Near Glencoul two dykes show this change, one for a

* The Stack of Glencoul is not named on the one-inch map, but it lies nearly two miles south-east from Glencoul cottage.

distance of about 170 yards, and the other for nearly half a mile, and for a third of a mile west of the last-mentioned dyke the gneiss above the thrust continues to strike parallel to the thrust, and is folded along axial planes that incline in the same direction as the line of disruption. Some of the gneiss near the higher thrusts and near the Moine-schist has been intensely crushed along parallel planes, which are coated with small scales of sericitic mica.

A little to the south-east of the middle of the section a narrow depression occupied by a siliceous crush-rock indicates the position of the great thrust (T), which in this district comes next above the Glencoul thrust. Gneiss appears on either side of the depression, but to the north-east the quartzite comes on with its basal conglomerate lying unconformably on the gneiss. A little above the conglomerate an intrusive sheet (F) makes its appearance. At a distance of more than a quarter of a mile from the base of the quartzite, and beyond four or five outcrops of sills, the pipe-rock (Cb) is reached. Its outcrop measures only 40 yards in width, and is overlain, not by the fucoid-shale, but by a band of serpulite-grit (Cd), which is in turn overlain by a thin stripe of limestone (Ce I.). In some places, however, the limestone is cut out entirely by another thrust, which brings up the basal quartzite once more. Besides this thrust there must also be another at the top of the pipe-rock, and perhaps a third within, or at the side of, the serpulite-grit. The thrust-plane which overlies the limestone is admirably seen in the roof of a cave hollowed out of the limestone. The plane inclines east at 22°, and the limestone below, for a depth of fifteen inches, has been broken up into lens-shaped pieces, often from three to six inches long, which are inclined to south-east, and are swathed round by thin calcareous laminæ.

A thin band of pipe-rock — the sub-division IV. in part —lies immediately under the sheared gneiss, and seems to have undergone a larger amount of shearing. It contains various thin bands which look like the sheared gneiss above, but which may represent sills. The general direction of the lines of movement on the shear-planes is about 34° north of west.*

Most of the Cambrian rocks in the south-east part of the section have been pushed forward on a thrust-plane which has a general north-westerly inclination, but perhaps the greatly-sheared pipe-rock just under the sheared gneiss lies on some still higher thrust-plane. These Cambrian rocks do not usually extend more than 100 or 200 yards from the section-line. On either side they are flanked either by the Lewisian gneiss, or, close to the south-east end of the section, by the basal quartzite which lies unconformably on this gneiss. They only form a thin veneer over the gneiss, as represented in Fig. 29. The thrust-plane has in some places been sharply folded, and bits of basal

* The alteration of the pipe-rock in this locality was fully described by Dr. Callaway in his "Notes on Progressive Metamorphism." *Geol. Mag.*, 1884, p. 218.

quartzite have been carried on it, and may be seen nipped into a steep cliff of gneiss.

At the base of the band of sheared gneiss which comes above the pipe-rock at the south-east end of the section a finely-sheared rock, about a foot thick, with laminæ hardly thicker than paper, looks as if it might possibly be a mixture of sheared gneiss and quartzite. Its laminæ are sometimes steeper than those of the quartzite below. The "Stack-schist"—as we have termed the band of schist above the sheared gneiss at the Stack of Glencoul—is part of the same band as the puckered schist with thin siliceous streaks which occurs at the south-west end of the section in Fig. 27 and at the south-east end of that in Fig. 28. The siliceous streaks at the Stack of Glencoul, and also many of those in other localities, differ from the sheared Cambrian quartzite in having a greenish-grey colour. The line between the mylonised rock and the overlying schist is tolerably well defined.

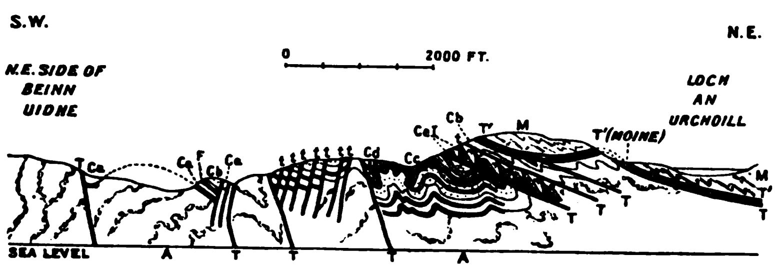

FIG. 30.—Section from the North-East Side of Beinn Uidhe to Loch an Urchoil.

A. Lewisian Gneiss. Ca. Basal Quartzite (Cambrian). Cb. Pipe-rock. Cc. Fucoid-beds. Cd. Serpulite-grit. Ce I. Ghrudaidh group. M. Eastern Schists. F. Intrusive Igneous Rocks. T. Thrusts. T′. Moine-thrust. t. Minor thrusts.

The section represented in Fig. 30 runs in a generally north-easterly direction, while the Cambrian rocks, the Moine-schists, and the thrust-planes have locally a N.N.W. strike. The folds to which this strike are due have not affected the unthrust quartzite or the Glencoul thrust-plane. They were probably developed while the masses which they affect were being thrust forward. The section only illustrates the north-eastern end of the large district affected by these cross folds. The higher thrusts and the Moine-schists are confined to the north-eastern half of the section.

The gneiss (A) at the south-western end is bounded on the north-east by a nearly vertical thrust, which has brought in the basal quartzite lying unconformably on gneiss which forms the centre of an anticline with N.N.W. axis and with the quartzite in both limbs. The conglomerate at the base of the quartzite is repeated by at least one small thrust. A thin sill (F), about two feet thick, appears below the conglomerate, and another one near the top of the basal quartzite. The quartzite is considerably sheared, and near the base contains some thin veins of quartz and felspar. In the eastern limb of the anticline the pipe-rock which there comes on is sharply folded along axes striking slightly west of north, but has an outcrop hardly 50 yards wide, for it is cut off on the east side by a north-west thrust, the plane of which sometimes dips steeply towards the west. This appears to be the Ben More thrust—one of the best-marked displacements in the district—but in the present line of section it has no special characters to distinguish it.

On the north-east side of what is believed to be the Ben More thrust, there comes first a patch of basal quartzite, then a steep thrust, beyond which lies a mass of gneiss crossed by several other steep thrusts, two of which unite with the Ben More thrust in a north-west direction. The gneiss is bounded on the north-east by another thrust mass, composed chiefly of quartzite, and lying between two thrusts striking slightly west of north. The quartzite mass is crossed by many lines of crush (tt), most of which have a steep dip towards the west and a downthrow in the same direction. In some parts of the mass a thin sill lies at the base of the quartzite, two others appear in the upper half of the basal quartzite, and one or two more near the top of the pipe-rock. The quartzite mass is succeeded by an area of fucoid-shale (Cc) and serpulite-grit (Cd) with a thin sill, but to the north-west of the line of section the Ghrudaidh limestone (Ce I.) also comes on in natural sequence above the grit, and on the south-east side a large mass of pipe-rock, which rises up from below the shale, is repeatedly folded along axes striking slightly north of west. The different zones are crossed by crush-lines which strike in the same direction. The throws along the lines are not large nor constant in direction, but the downthrow seems always in the direction of hade. The top zone is somewhat shaly and more cleaved than the massive rocks below, and contains a number of thin veins of quartz and felspar.

Further north-east the section shows a narrow area chiefly composed of thin stripes of Ghrudaidh limestone (Ce I.), serpulite-grit (Cd), and sheared sills. These strike against the exposures of fucoid-shale, serpulite-grit, and limestone referred to in the last paragraph, and are separated from them by a thrust-plane which strikes N.N.W. They are disturbed by minor thrusts (t) as well as folds, and the thrust (T) below may be regarded as a sole. Above the stripes of serpulite-grit and limestone, pipe-rock (Cb) comes in, frequently folded into isoclines with both limbs dipping gently to north-east. The pipes often make angles of about 45° with the bedding, and the rock cleaves readily along them.

Still further to the north-east, on the slopes above Loch an Urchoil, a small exposure of basal quartzite (Ca) rises up from below a denuded anticline of the thrust-plane on which the overlying schist rests. This quartzite, which has been sheared into thin laminæ that show close parallel lines of movement running about west 20° north, appears to lie on a still higher thrust-plane than the pipe-rock mentioned in the last paragraph.

Above the sheared pipe-rock, a zone, rarely more than ten feet thick, is composed of thin bands of quartzite and some mylonised rock. The quartzite bands have been folded into isoclines with both limbs inclining to north-east. They sometimes contain thin quartz-felspar veins which have not been sheared. The mylonised rock, with its small eyes of felspar and streaks which look like sheared pegmatite, has probably been derived in the main from Lewisian gneiss. It is surmounted by a schist (M) like that in the Stack of Glencoul. This rock has been folded along axes striking north-west, first, into a syncline, and then, further north-east, into an anticline. Beyond the anticline the general dip is to north-east at angles varying between 15° and 30°, and on the north-east side of Loch an Urchoil comes the mass of granulitic Moine-schists like those on Beinn Lice.

CHAPTER XXXV.

STRUCTURE OF ASSYNT, FROM LOCH GLENCOUL TO KNOCKAN AND THE CROMALT HILLS.*

In the mountainous region of Assynt extending from Glencoul to Knockan and the Cromalt Hills, where the belt of complication is from six to eight miles broad, the following tectonic features are so fully presented as to invest this district with special interest and importance:—

1. In the northern part of the area three major lines of disruption—the Glencoul, the Ben More, and the Moine thrusts—follow each other in definite order from west to east. The first and most westerly brings forward the Lewisian gneiss, covered unconformably by Cambrian strata; the second, a slice of Lewisian rocks and Torridon Sandstone with the double unconformability of the Cambrian quartzites; and the third, the Eastern or Moine schists.

2. In the central and southern parts of the district each of the two lower thrusts is in turn overlapped by the one to the east till the Eastern schists rest directly on undisturbed Cambrian strata. This striking feature distinguishes the ground in Assynt from the rest of the belt of complication in the North-West Highlands.

3. The Ben More thrust-plane has been folded, and the important outliers of the materials which surmount it, showing the double unconformability, are met with from two to five miles west of its main outcrop.

4. The various sills of post-Cambrian igneous rocks are found occupying their respective horizons in the displaced masses above the Glencoul and Ben More thrust-planes, thereby proving the wide distribution of these intrusions before the movements.

Immediately to the south of Loch Glencoul the tectonic arrangement of the strata is precisely the same as that on the north side of the loch, described in the last chapter. The undisturbed Cambrian rocks from the basal quartzites to the fucoid-beds, dipping to the E.S.E. at 12°, are there overlain by the piled-up members of the Middle Series, which, repeated by reversed faults, are truncated by the Glencoul thrust. This important displacement brings forward the southern continua-

* By B. N. Peach and J. Horne. The district described in this chapter is contained in Sheets 101, 102, 107, and 108 of the Geological Survey Map of Scotland, on the scale of 1 inch to a mile ($\frac{1}{63360}$).

tion of the moved gneiss with its basic dykes north of Loch Beag, the thickness of the mass varying from 1500 to 1600 feet. The imbricate arrangement of the fucoid-beds and serpulite-grit beneath that line of disruption and the bare plane itself are well seen along the course of a footpath which traverses the slope on the south side of the loch.

Southwards beyond Loch na Gainmhich the north-west slope of Glas Bheinn exposes the thrust gneiss covered unconformably by the basal quartzites and pipe-rock in their natural order, the whole displaced mass resting on the Glencoul thrust-plane. Not far to the south of this point the relations of the strata become much more complicated, as shown in the accompanying section, across the northern part of Assynt.

On the southern slope of Quinag the unconformability between the quartzites and the Torridon sandstones (Bb) is clearly seen (Fig. 31), the former dipping towards the E.S.E. at angles varying from 4° to 8°, while the inclination of the latter is in the same general direction at from 15° to 20°. Both zones of the Cambrian arenaceous series (Ca, Cb) are followed in normal sequence by the fucoid-beds and serpulite-grit (Cc, Cd); but close to the high road leading to Kylesku the undisturbed strata are cut off by a major thrust-plane or "sole" (T), along which the fucoid-beds, serpulite-grit, and basal dolomite have been driven, being repeated by numerous reversed faults (t). This imbricate structure is merely a repetition of that above described on the north side of Loch Glencoul and at Heilim in Loch Eireboll. As an instance of the rapid reduplication of the beds, it may be mentioned that thirteen outcrops of the serpulite-grit appear here within a third of a mile. Near Achumore, another major thrust ushers in the basal dolomites with the igneous sills (F) lying at gentle angles and resting on the thrust strata just described. These are followed by the members of the two lowest groups (I., II.), both sub-divisions being repeated by various reversed faults, and folded in gentle arches and troughs, till the Calcareous series is over-ridden by the materials above the Glencoul thrust-plane. Owing to the covering of morainic drift, the outcrop of this line of disruption east of Achumore is concealed, but its position is approximately at the base of the steep slope that runs southward from Glas Bheinn.

Above this thrust-plane and along the south-west declivity of the mountain, the various sub-zones of the pipe-rock (Cb), with the porphyrite sills (F), appear in inverted order, succeeded by the basal quartzites resting unconformably on the Archæan rocks with the basic dykes, which there preserve their north-west trend. The inversion of the Cambrian strata, so conspicuously displayed on this slope of Glas Bheinn, is an example of the usual folding over and buckling under of the strata in front of the displaced masses of gneiss. In this line of section a small thrust drives the Lewisian rocks on to the basal quartzites, but both to the north and south of this locality the inverted base line of the Cambrian sequence can be traced. On the east side of the

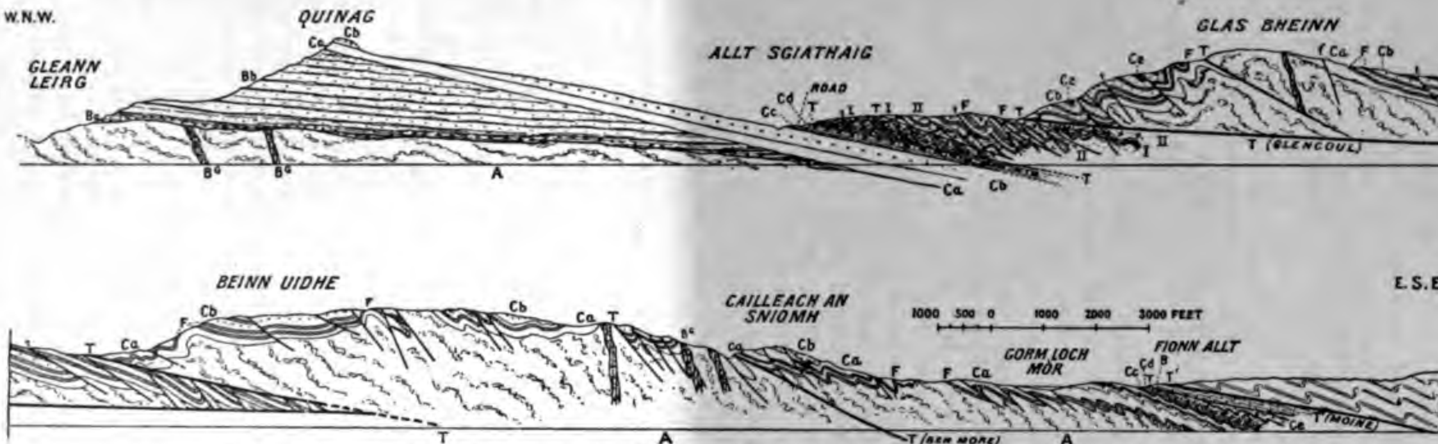

FIG. 31.—Section from Quinag by Glas Bheinn and Beinn Uidhe to Gorm Loch Mór and Fionn Allt.

A. Lewisian Gneiss. Bg. Dykes in Gneiss. B. Torridon Sandstone. Ba. Diabeg group (Torridonian). Bb. Applecross group. Ca. Basal Quartzite (Cambrian). Cb. Pipe-rock. Cc. Fucoid-beds. Cd. Serpulite grit. Ce. Limestone (Cambrian). Ce I. Limestone (Grudaidh group.) Ce II. Limestone (Eilean Dubh group). F. Intrusive Igneous Rocks. M. Eastern Schists. T. Thrusts. T'. Moine-thrust. t. Minor thrusts. f. Faults.

Lewisian inlier both divisions of the arenaceous series (Ca, Cb) follow in natural sequence together with their intrusive sheets.

Between Glas Bheinn and Beinn Uidhe a thrust, intermediate between the Glencoul and Ben More disruptions, intervenes and repeats both the basal quartzites and the pipe-rock, which, on the lofty plateau of Beinn Uidhe, are arranged in a gentle synclinal fold. Sheet 107 of the map shows that the sills of igneous material (F), which there occur near the top of the lower division of the quartzites, have been traced round this great flexure. Along the north-east slopes of Glas Bheinn and Beinn Uidhe the basal beds of the arenaceous series (Ca) rest unconformably on the gneiss save where small local thrusts intervene. Eastwards on the high plateau beyond Beinn Uidhe the Lewisian rocks again rise from underneath the thin veneer of quartzites, which have there been thrown into numerous small folds and repeated by reversed faults.

Descending the ridge towards Cailleach an Sniomh—a hill west of Gorm Loch Mor—we cross the outcrop of the Ben More thrust-plane, which there gives rise to a well-marked hollow. (Fig. 31.) This disruption has brought westwards the Lewisian rocks with both divisions of the arenaceous series on to the basal quartzite. Three characteristic intrusive sheets appear in this area, one at the base of the false-bedded Cambrian grits, a second higher up in the same sub-division, and a third in the lowest subzone of the pipe-rock. South of Gorm Loch Mor the evidence is much obscured by an extensive covering of moraines, but north of that lake the fucoid-beds, serpulite-grit, and basal dolomite are repeated mainly by folding, and a similar arrangement of the strata is observable near the Fionn Allt. At the latter locality a lenticle of mylonised Torridon arkose (B) underlies the Moine thrust-plane (T′), above which the great series of Eastern schists supervenes.

At its western limit the section (Fig. 32) shows the mode of occurrence of the intrusive sheets of albite-porphyrite (F), which are such a prominent feature in the Torridon sandstones (B) and Cambrian quartzites (Ca) on Beinn Gharbh. Allusion has already been made to the double unconformability on the north slope of that hill, where the basal quartzite, overlapping the Torridon Sandstone, comes to rest directly on the Lewisian gneiss. Next follow in order the sub-divisions of the pipe-rock (Cb), dipping E.S.E. at an angle of about 15°. The highest subzone pierced by the intrusive sill is that of the "trumpet" pipes. From the eastern side of the alluvium at the head of Loch Assynt rise the piled-up fucoid-beds, serpulite-grit, and basal dolomite charged with *Salterella*. Two basic sills are here interposed, one between the serpulite-grit and the bottom of the Calcareous series, and the other in the Ghrudaidh group (I.) These are followed by the Eilean Dubh dolomites and limestones (II.) resting on different members of the lowest division of the Calcareous series and repeated by reversed faults. That the dolomites and limestones in this portion of the plateau are not

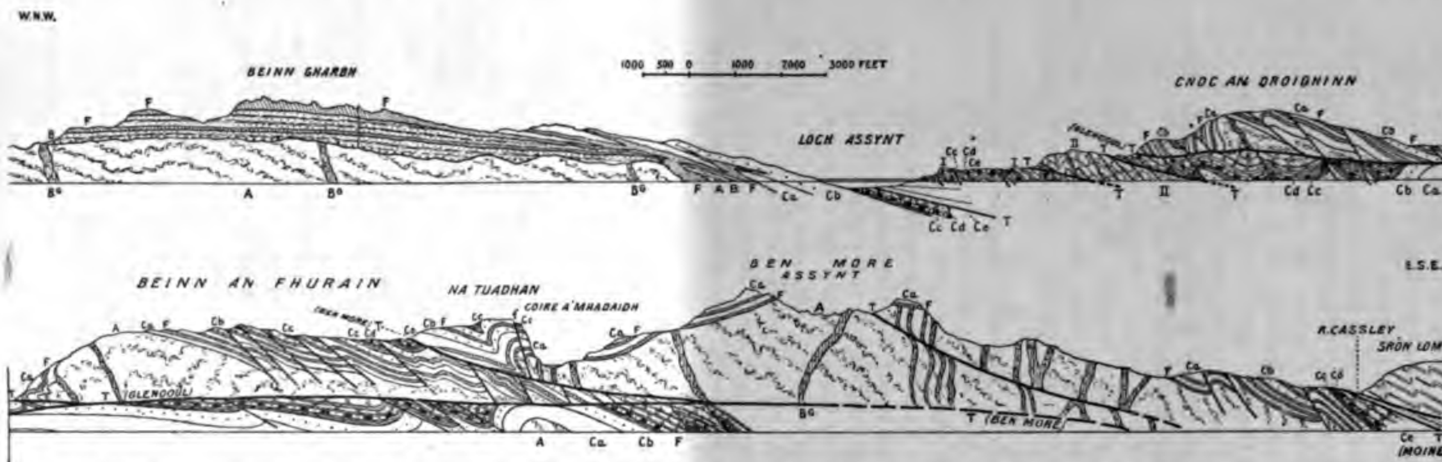

FIG. 32.—Section from Beinn Gharbh by Cnoc an Droighinn, Beinn an Fhurain, and Ben More, Assynt, to the River Cassley.

A. Lewisian Gneiss. Bg. Dykes in Gneiss. B. Torridon Sandstone. Ca. Basal Quartzite (Cambrian). Cb. Pipe-rock. Cc. Fucoid-beds. Cd. Serpulite-grit. Ce. Limestone. Ce I. Limestone (Ghrudaidh group). Ce II. Limestone (Eilean Dubh group). F. Intrusive Igneous Rocks. M. Eastern Schists. T. Thrusts. T'. Moine-thrust. f. Faults.

arranged in an inverted synclinal fold can be demonstrated in a conclusive manner, for within a distance of half a mile from Loch Assynt the piled-up limestones are truncated by another major thrust, which has brought up the fucoid-beds, serpulite-grit, and basal dolomites, and has pushed them above the Eilean Dubh beds. This displacement can be traced northwards to the Chalda Burn and southwards across the Traligill to the limestone east of Stronechrubie.

About half a mile north-east from Inchnadamff Hotel the position of the Glencoul thrust-plane is defined by a well-marked feature which skirts the escarpment of quartzites on the west slope of Cnoc an Droighinn. These strata have here been driven on to the dolomites of the Ghrudaidh group. Though complicated by the recurrence of minor thrusts and the presence of numerous sills of igneous material, both divisions of the quartzites on that hill may be described generally as forming an inverted anticline and syncline on a core of gneiss. The fucoid-beds, the highest members of the series represented in the trough, are cut off on the east side by a reversed fault. Two intrusive sheets of porphyrite (F) here occur near the top of the lower division of the quartzites (Ca), and one of ægirine-felsite near the base of the lowest sub-zone of the pipe-rock. Another example of the latter type appears in a higher sub-zone in Allt Poll na Droighinn.

East of Cnoc an Droighinn a thrust occurs, which is the southern continuation of that west of Beinn Uidhe, and, like it, brings forward a mass of Lewisian gneiss (A) with basic dykes exposed on the north-west slope of Beinn an Fhurain. The basal quartzites (Ca) resting unconformably on the Lewisian floor can be traced round this inlier, though frequently in an inverted position. Eastwards the crest of the mountain is mainly composed of pipe-rock (Cb), overlain by fucoid-beds (Cc) and serpulite-grit (Cd), repeated by minor thrusts, and accompanied by intrusive sheets which resemble the types on Cnoc an Droighinn and occupy similar horizons.

The position of the outcrop of the Ben More thrust, which is the second great line of displacement in the Assynt region, lies on the east side of the peaty hollow between Beinn an Fhurain and Na Tuadhan, but the outcrop itself is there obscured by quartzite debris. Though not visible in this line of section, it is laid bare in the Beallach or pass between Na Tuadhan and Coinne-mheall, about a quarter of a mile south of the top of the former mountain.

The stupendous folds of Cambrian strata on Na Tuadhan, in advance of the great displaced mass of Lewisian gneiss of Ben More, are among the most impressive geological features in Assynt. (Plate XXXIV.)* This mountain, which rises to a height of 2824 feet, with a cliff about 1100 feet high on its eastern face. partly bounds the great corrie on the north-west side of Ben

* Plate XXXIV. forms the frontispiece of this volume.

More. Above the thrust-plane both divisions of the Cambrian quartzites (Ca, Cb) are arranged in a great inverted arch and trough, which are readily recognised from the surrounding peaks. The unconformable boundary line between the basal quartzites and the Lewisian gneiss can be followed round the base of the great crag on the east side of the mountain, and northwards for more than a mile to Corrie Mhadaidh Beag, with a porphyrite sill along the junction. Outliers of this intrusive sheet, sometimes capped with basal quartzite, are found resting on the gneiss on the floor of Corrie Mhaidaidh, indicating the former continuation of that series southwards towards the slope of Ben More. It is noteworthy that a common cleavage foliation affects the outlying portions of the porphyrite and the Lewisian gneiss beneath, the planes being more or less parallel with the plane of the Ben More thrust. Two additional sills appear in the basal quartzites, and one in the third sub-zone of the pipe-rock.

But the most striking structural feature here is the sharply-inverted syncline which runs down the south-east side of the mountain for more than a thousand feet, and involves all the subdivisions of the Cambrian strata from the fucoid-beds (Cc) down to the thin pebbly grit at the base, together with the intrusive sheets (F) and the underlying floor of gneiss. The synclinal fold is followed by an arch, which is truncated by a normal fault with a downthrow towards the north-east.

The line of section in Fig. 32 now traverses Ben More, Assynt, where the structure becomes comparatively simple. On the declivity facing Corrie Mhadaidh the basal quartzite (Ca) with the intrusive sheets (F) forms a thin veneer on the great mass of Lewisian gneiss and basic dykes, to which attention will be immediately directed. Though the quartzites here are not deformed, the porphyrite sill at the base of the arenaceous series is highly sheared.

On the far eastern slope of Ben More, towards the head waters of the River Cassley near Sron Lom, the Lewisian rocks are covered unconformably by the basal quartzite (Ca), followed by all the sub-zones of the pipe-rock (Cb), the fucoid-beds (Cc), the serpulite-grit (Cd), and the basal dolomites of the Ghrudaidh group (Ce), traversed by a few reversed faults. Here the various sills in the arenaceous series occupy their proper respective horizons. As the rocks are followed eastwards their deformation becomes more pronounced in the intrusive sheets, the quartzites, and the fucoid-beds. Still further east a narrow wedge of sheared Torridon Sandstone (B in Fig. 32) has been driven on to these displaced strata, but it is soon truncated by the Moine thrust which brings in the Eastern schists.

The geological structure of the southern part of Ben More and of Coinne-mheall—its western peak—is much more complicated. Between the latter mountain and Breabag a narrow pass, termed the Beallach, separates the head waters of the Oykell River from the sources of the Traligill. On the northern slope of this defile the outcrop of the Ben More thrust is clearly seen in dip section, and the relations of the thrust masses may be studied in detail in the crags which stretch eastwards to the corrie surrounding Dubh Loch Mor. The structure of this complex ground is explained in Figs. 33 and 34.

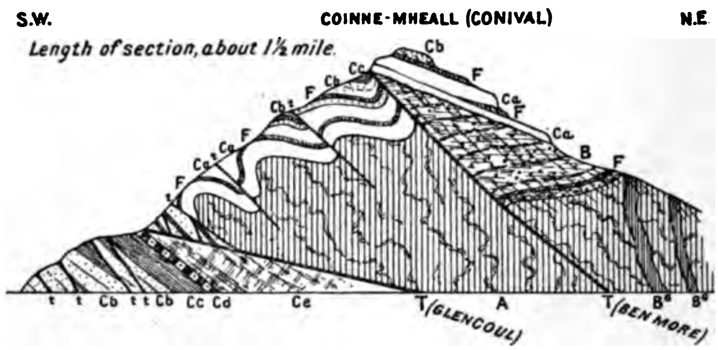

FIG. 33.—Section across Coinne-Mheall from one of the sources of the Traligill east to Corrie a' Mhadaidh.

A. Lewisian Gneiss. Bᵅ Dykes in Gneiss. B. Torridon Sandstone. Ca. Basal Quartzite (Cambrian). Cb. Pipe-rock. Cc. Fucoid-beds. Cd. Serpulite-grit. Ce. Limestone. F. Intrusive Igneous Rocks. T. Thrusts. t. Minor thrusts.

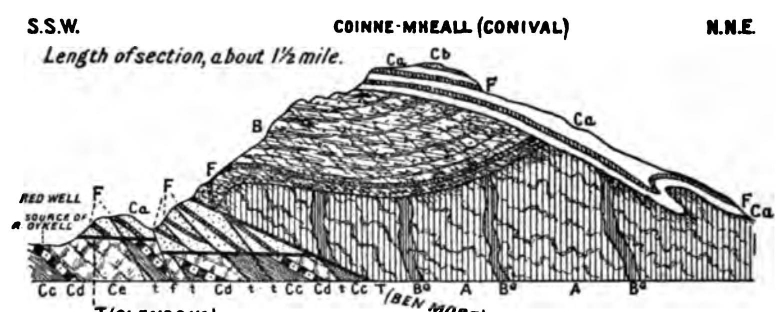

FIG. 34.—Section from the Bheallach across Coinne-Mheall to Corrie a Mhadaidh.

A. Lewisian Gneiss. Bᵅ Dykes in Gneiss. B. Torridon Sandstone. Ca. Basal Quartzite (Cambrian). Cb. Pipe-rock. Cc. Fucoid-beds. Cd. Serpulite-grit. Ce. Limestone. F. Intrusive Igneous Rocks. T. Thrusts. t. Minor thrusts. f. Faults.

At the bottom of the western slope (Fig. 33) the basal quartzites are seen to have been driven on to the Cambrian dolomites by the Glencoul thrust. As the burn-section on this declivity is followed up to the 2500-feet contour line, the strata exposed are found to consist almost wholly of these quartzites (Ca) with their sills (F). They are repeated by inverted folds and minor thrusts (t) in such a way as to indicate that these must form only a comparatively thin veneer over the concealed Lewisian rocks. About the 2500-feet level the basal quartzites are followed in order by the various sub-divisions of the pipe-rock (Cb) with their sills, until these rocks are abruptly truncated by the Ben More thrust-plane (T). At the place where the line of section in Fig. 33 is drawn the effect of this great disruption has been to drive the basal quartzites over the highest zone of the pipe-rock (Cb) and fucoid-beds (Cc). When the false-bedded grits (Ca) are traced along the crest of the mountain they are found to overlie unconformably both the Torridon Sandstone (B) and the Lewisian gneiss (A). On the summit the basal quartzites are succeeded by the lowest sub-division of the pipe-rock (Cb). In descending the north-eastern slope of Coinne-mheall the observer crosses the unconformable junction of the basal quartzites with the Torridon Sandstones, and likewise the boundary between the latter and the Lewisian rocks. (Fig. 34.)

Owing to the high inclination of the Ben More thrust-plane its outcrop here descends from the crest of the mountain to the Beallach. As a result of the friction along the unyielding "sole" of the thrust, causing the upper layers to move more rapidly than the lower, the Torridon Sandstones have been folded over the western face of the disrupted gneiss, as shown in Fig. 34. By means of the local conglomerate at the base the line of junction with the old Lewisian platform is easily traced, and the proof of inversion is thus placed beyond doubt. The basal conglomerate and the overlying grits, sandstones, and shales can be followed continuously from the Beallach, round the south-eastern spur of Coinne-mheall to the southern shoulder of Ben More, where they are unconformably overlain by a cake of the basal quartzites. (Plate XXXV.) The area occupied here by the Torridon Sandstone is about half a square mile, about half of which is buried under the basal quartzites. The general inclination of these grits and sandstones is towards the W.N.W. at an average angle of 20°; the greatest thickness is about 1500 feet.

From his descriptions it is evident that Nicol recognised these green grits and sandstones as the true western red sandstone (Torridon) brought up in the centre of the so-called "upper quartz-rock." Hence he inferred that the syncline to the west is complete in all the formations from the upper limestone to the lowest gneiss.* He further stated that granitic gneiss and mica slate with intrusive igneous rocks form the nucleus of the mountain, throwing off the quartzite all around, as from a great centre of elevation.

In the Beallach of Coinne-mheall the dip of the Ben More thrust-plane becomes almost flat, and hence the outcrop can be followed for two miles and a half down the River Oykell. Along the line of outcrop the Torridon Sandstones with their basal conglomerate (the "button stone") reappear on the east side of the valley, dipping underneath the Lewisian gneiss in inverted

* *Quart. Jour. Geol. Soc.*, vol. xvii., pp. 96–99; also Fig. 8, p. 96.

Lewisian Gneiss forming lowest part of cliff (I.), covered by Torridon Sandstone in middle distance (II.), capped by basal quartzites (III.) on crest of Ben More, Coire Dubh Loch Mòr, Sutherlandshire.

Plate XXXVI.

Thrust Dolomite and Limestones. Stronechrubie Cliffs, Inchnadamff, Sutherlandshire.

order. There can be no doubt, however, that this strip of Torridon strata is merely a continuation of the mass on Coinne-mheall and Ben More, as shown in section (Fig. 35), the intervening portion having been removed by denudation.

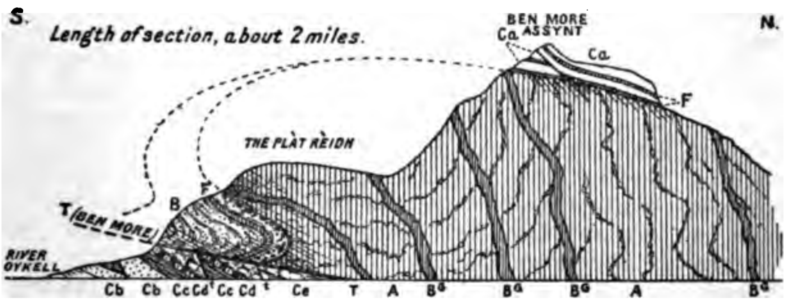

FIG. 35.—Section from the Oykell Valley across the Plat Reidh and Ben More, Assynt.

A. Lewisian Gneiss. Bᵅ. Dykes in Gneiss. B. Torridon Sandstone. Ca. Basal Quartzite (Cambrian). Cb. Pipe-rock. Cc. Fucoid-beds. Cd. Serpulite-grit. Ce. Limestone. F. Intrusive Igneous Rocks. T. Ben More thrust. t. Minor thrusts.

In his account of the geological structure of the Assynt district, Dr. Callaway noted the superposition of the Torridon grits on the Hebridean gneiss on Coinne-mheall and Ben More, and the inversion of these sediments beneath the same mass of gneiss on the east side of the Oykell valley (Fig. 35). He inferred that these appearances seem inexplicable except on the supposition of an overthrow of the gneiss and grit upon the dolomite.*

The outcrop of the great Ben More thrust-plane can be followed southwards from the Oykell valley, round the western slope of Sgonnan Mor, by Strathsheaskich, thence to Allt an Loin Dhuibh, and round Cnoc na Glas Choille to the base of the Cromalt Hills (in one-inch Sheet 101), where it is overlapped by the Moine thrust-plane. It is worthy of note also that the Glencoul thrust is not traceable further south than a point near the Beallach between Coinne-mheall and Breabag, being there overlapped by the Ben More disruption.

The broad plateau of the Calcareous series at Inchnadamff lies almost wholly within the area affected by the post-Cambrian movements. In the Stronechrubie cliff the fucoid-beds, serpulite-grit, the Ghrudaidh dolomites, and part of the Eilean Dubh group follow each other in natural order, with a prominent igneous sill on the horizon of Sub-zone 7, in the Ghrudaidh sub-division. The upper part of the cliff shows a well-marked thrust-plane or "sole," upon which, and tilted at an angle to it, the calcareous beds of the Eilean Dubh group rest. (See Plate XXXVI.) This disruption, along which a sheet of crushed

* *Op. cit.*, vol. xxxix., p. 382; also Fig. 6., p. 383.

igneous rock appears at intervals, is traceable northwards to a point on the Traligill River, about 300 yards east of Inchnadamff Hotel. Again, on the slope south of the Traligill Burn at Glenbain, about six major thrusts are seen in dip-section, the beds between these planes being piled up by minor reversed faults.

East of Stronechrubie the calcareous rocks, representing the Ghrudaidh, Eilean Dubh, and Sail Mhor groups, are arranged generally in a great synclinal fold, the strata, with their accompanying sills, being piled up by numerous major and minor thrusts. One of the finest examples of a bare thrust-plane in the limestone plateau may be seen in the Traligill River, about a mile up stream from the Inchnadamff Hotel, where the Ghrudaidh dolomites (Group I.) have been driven over the Eilean Dubh beds (Group II., see Plate XXXVII.) It frequently happens that the water descends and flows along these divisional planes beneath the surface, reappearing at lower levels. Occasionally outliers of the fucoid-beds and serpulite-grit are found capping the Eilean Dubh dolomites and limestones in the north-west part of the plateau, separated from each other by major thrusts. But subsequent to these various displacements whereby the strata were driven together, the area along the north-eastern and eastern margins of the limestone-plateau was elevated in the form of a great dome. Hence at intervals various sections may be observed which show the natural passage from the pipe-rock to the fucoid-beds, serpulite-grit, and basal dolomites, the strata dipping towards the west. This feature is illustrated on the slopes of Breabag; likewise beyond the Traligill near Glenbain, where the members of the Middle Series rise from underneath the thrust dolomites and are underlain by the pipe-rock and basal quartzites, which there form a normal arch—the continuation of the anticlinal structures on Breabag. (Sheet 107.)

South of Inchnadamff various outliers of the materials that overlie the Ben More thrust-plane have been left by denudation on the displaced masses. The most important of these occur on Cnoc an Leathaid Bhuidhe west of Loch Awe, on the moor south of Loch Urigill, and on the limestone-plateau south-east of Stronechrubie. The two isolated examples, north and south of Allt nan Uamh, are of special interest, as they show the original folding of the Ben More thrust-plane and its overlap of the Glencoul thrust-plane. (Sheet 101.)

On the slopes of Canisp (Fig. 36) the double unconformability of the quartzites (Ca, Cb) on the Torridon Sandstone (Bb) and on the Lewisian rocks (A) is exposed, the strata being intersected by several normal faults (ff). East of the Loanan indications may be observed of the piling-up of the Middle Series and basal dolomite by reversed faults, which are truncated by a major thrust that has brought westwards the two lowest groups of dolomite and limestone. On the line of section the basal quartzites appear in inverted order above the Ben More thrust-plane (T),

Bare inclined thrust-plane or "sole" in Cambrian Limestone. Traligill River, Inchnadamff, Sutherlandshire.

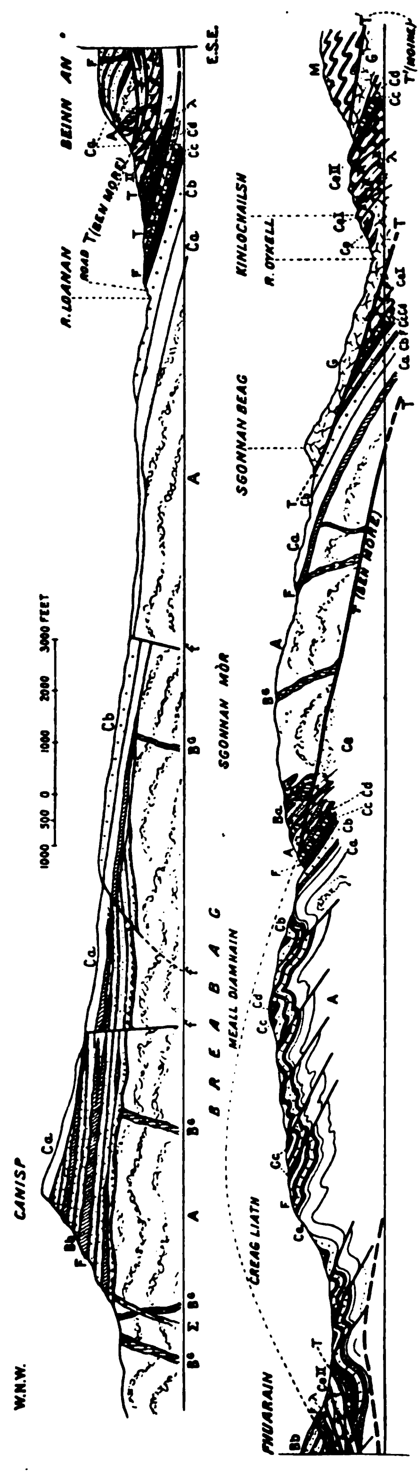

FIG. 36.—Section from Canisp by Beinn an Fhuarain, Breabag, and Sgonnan Mòr to Kinlochailsh.

A. Lewisian Gneiss. BG. Basic Dykes in Gneiss. Σ. Ultra-Basic Dyke in Gneiss. Ba. Diabaig group (Torridonian). Bb. Applecross group. Ca. Basal Quartzite (Cambrian). Cb. Pipe-rock. Cc. Fucoid-beds. Cd. Serpulite-grit. Ce. Limestone. Ce I. Limestone (Ghrudaidh group). Ce II. Limestone (Eilean Dubh group). λ. Marble (Cambrian). F. Porphyrite Sills. G. Syenite. M. Eastern Schists. T. Thrusts. T'. Moine thrust. f. Faults.

but on the north-west face of Beinn an Fhuarain the pipe-rock rises from below these false-bedded grits, the beds being inclined to E.S.E. at rather high angles. Near the hill-top the unconformable junction of the basal quartzites on the Torridon sandstones is exposed, and when followed southwards the false-bedded quartzites pass transgressively across the Torridon Sandstone till they rest directly on the gneiss (A). Only a small exposure of the gneiss is there met with, but it contains one of the basic dykes. (Sheet 101.)

The outcrop of the thrust-plane forms a well-marked feature round this inlier, and is seen in dip-section on the north-east shoulder of the ridge, near the caves of Allt nan Uamh, where the Torridon Sandstone rests directly on the Eilean Dubh limestone. The Allt nan Uamh, by carving a deep channel through the underlying calcareous rocks, has isolated the outlier on Beinn an Fhuarain, which is over a mile in length, from the smaller mass on Beinn nan Cnaimhseag on the north side of the stream. (Sheet 101.) Along the north margin of the latter outlier the bare thrust-plane of Eilean Dubh dolomite is well displayed. It is inclined to the west at 15°.

In the hollow between Beinn an Fhuarain and Breabag the members of the Middle Series reappear, followed by the quartzites with a westerly dip. On Creag Liath the beds of the lower division (Ca) are exposed on the crest of an arch, and the successive zones of pipe-rock and intercalated sills (F) can be traced in normal order round the fold. The broad dome of Breabag consists of a compound anticline, chiefly composed of thrust zones of the pipe-rock (Cb) and fucoid-beds (Cc). At one place the *Salterella* grit (Cd) is found on the high plateau. A striking feature of the mountain is the repetition by folds and reversed faults of two intrusive sheets (FF), one in Zone III. of the pipe-rock and the other in Zone V. of that division or in the fucoid-beds. In the pass between Breabag and Sgonnan Mor the highest zone of the pipe-rock is followed by the fucoid-beds, serpulite-grit, and, at one place, by the basal dolomite, with intrusive sills of hornblendic rocks in both members of the Middle Series (Cc, Cd), these higher sub-divisions being abruptly cut off by the Ben More thrust.

The evidence as to tectonic arrangement furnished by the materials overlying this great plane of disruption on Sgonnan Mor is merely a counterpart, on a smaller scale, of that supplied by Ben More, Assynt. Here a considerable mass of Lewisian gneiss (A) appears with its basic dykes, and with the Torridon Sandstone (Ba) inverted beneath it; the double unconformability of the basal quartzites is displayed, and some of the characteristic intrusive sheets are to be seen on their respective horizons. On the line of section in Fig. 36 an inverted synclinal fold of Torridon Sandstone (Ba) may be observed on the western face of displaced gneiss. This fold is continuous with that on the south-west slope to be referred to in the sequel. (See Fig. 37.) The position of the thrust-plane is here clearly defined, as the rocks are bare of drift and their distinctive lithological characters make them readily distinguishable from each other. Close to the disruption the Lewisian rocks are sheared, but eastwards the pyroxene-gneiss and hornblende-biotite-gneiss are not much deformed. They are traversed by dykes of epidiorite and in one case by a dyke of peridotite with their normal north-west trend. A short distance to the east of the hill-top the lower division of the quartzite (Ca) rests unconformably on the gneiss with an intervening sill of porphyrite (F), and when traced southwards these strata are seen resting upon the Torridon Sandstone on the south-western declivity. The false-bedded quartzites are succeeded by the pipe-rock, which is then cut off by a thrust that has carried westwards a mass of syenite similar to that at Cnoc na Sroine. (Chapter XXIX.) Covering an area of about three square miles, this eruptive rock is bounded along its western margin by a thrust-plane, and passes transgressively across the Lewisian rocks, both divisions of the quartzites, the fucoid beds, and serpulite-grit. On its eastern side near Kinlochailsh it is intrusive in the lower zones of the Calcareous series, which are there converted into marble (λ), and further north it traverses the fucoid-beds. East of the marble at Kinlochailsh a narrow band of sheared granitoid rock (G) appears below the Moine thrust-plane (T′), which evidently belongs to the same series of intrusions. This great displacement, as in sections already described, here ushers in the enormous series of the Eastern schists (M).

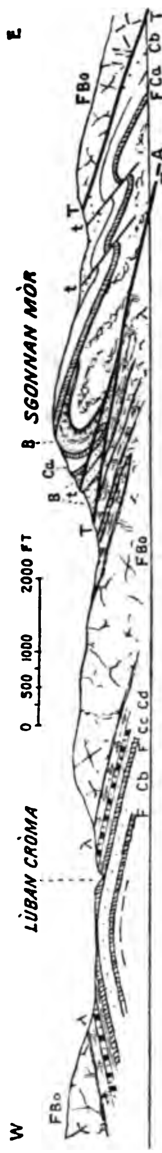

FIG. 37.—Section from Lùban Cròma across Sgonnan Mòr.

A. Lewisian Gneiss. B. Torridon Sandstone. Ca. Basal Quartzite (Cambrian). Cb. Pipe-rock.
Cc. Fucoid-beds. Cd. Serpulite-grit. λ. Marble (Cambrian). FBo. Borolanite.
F. Porphyrite Sills. T. Thrusts. t. Minor thrusts.

The relations of the eastern continuation of the plutonic mass of Cnoc na Sroine east of Luban Croma to the materials overlying the Ben More thrust-plane are shown in Fig. 37. The valley of the Ledbeg River above the Loyne displays this extensive igneous intrusion on its south side and the Cambrian quartzites of the Breabag ridge on the north. Where the rocks are not concealed by peat and drift the fucoid-beds, serpulite-grit, and marble rise from underneath the mass of syenite and borolanite (FBo)—as, for example, at Luban Croma, situated about a mile and a half N.N.E. from Aultnacallagach Inn. At that place the members of the Middle Series follow the pipe-rock zones round the anticlinal structures of Breabag. Beyond the syenite east of Luban Croma, sills of borolanite, as already indicated, appear in association with the marble in the small streams draining the south-west slope of Sgonnan Mor towards the Ledbeg River. In one of these streams the sheared granitoid rock (borolanite) below the Ben More thrust-plane and the Torridon grits above that plane may be traced to within a few yards of each other. On the slope the Torridon shales, sandstones, and grits dip eastwards in inverted order beneath the Lewisian gneiss, till the local basal conglomerate of the Torridonian series is seen in contact with its old floor of gneiss. The pebbles in this conglomerate consist mainly of white quartz.*

Further to the south-east, on the south slope of Sgonnan Beag, the position of the Ben More thrust-plane is obscured by peat and drift, but above it a small infold of the basal quartzites has been detected in the Torridon Sandstone, while further east these quartzites rest directly on the Lewisian gneiss, and are followed by the pipe-rock.

East of the undisturbed Cambrian strata north of Cam Loch (Sheet 101) a belt of extremely complicated ground stretches between Ledbeg Hill and the western base of Cnoc na Sroine. As shown in Fig. 38, the Ben More thrust-plane in a nearly horizontal position extends across that area and carries on its "sole" outliers of displaced materials, which, separated by denudation, rest on various zones of the Cambrian system that have been affected by the movements. This tract is further complicated by the metamorphism of the Cambrian strata by the igneous intrusions already described, while part of the ground is also obscured by peat.

The most westerly outlier which covers the top and southern slope of Ledbeg Hill overlooking Cam Loch contains a core of Lewisian gneiss (A), with the basal quartzite (Ca) inverted near the thrust-plane, and dipping in normal order on the crest of the hill, followed by the pipe-rock (Cb) in the north-east corner of the displaced materials. Eastwards towards the Ledbeg River the rocks underlying the Ben More thrust-plane consist mainly of altered Cambrian limestone, chiefly of the Eilean Dubh group, pierced by granitic intrusions, while all the outliers above that plane are composed of basal quartzites, save the most easterly, which includes a portion of the pipe-rock.

As represented in the section (Fig. 38), the plane of the Ben More thrust, which once overlay the large eruptive mass (G), has there been removed by denudation. Its position and the connection of its severed parts are shown by the dotted line above the

* This inversion was recognised and described by Dr. Callaway. *Quart. Jour. Geol. Soc.*, vol. xxxix., p. 382.

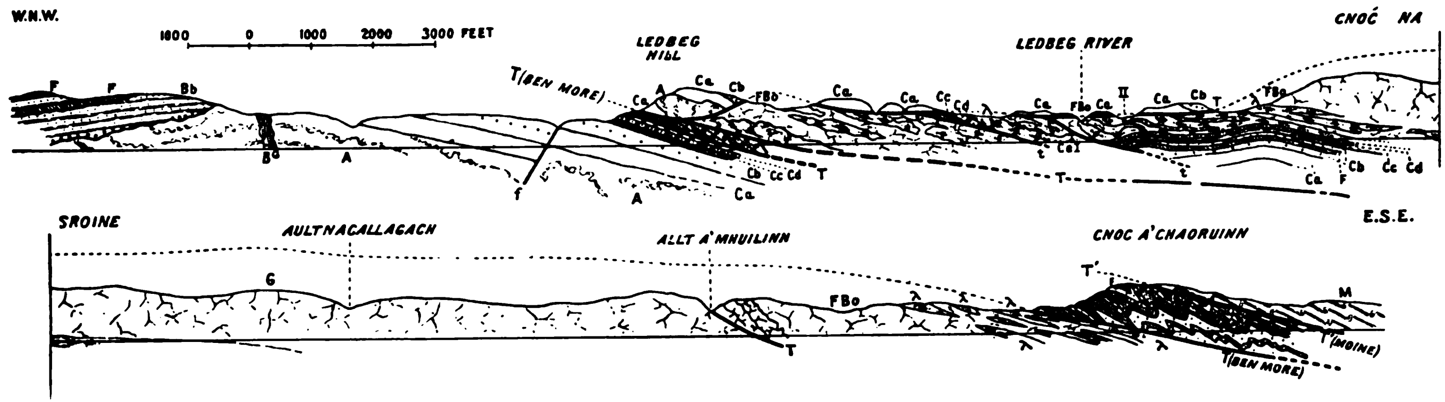

Fig. 38.—Section from Ledbeg Hill by Cnoc na Sroine to Cnoc a' Chaoruinn.

A. Lewisian Gneiss. Bᴳ. Dykes in Gneiss. Bb. Applecross Group (Torridonian). Ca. Basal Quartzite (Cambrian). Cb. Pipe-rock. Cc. Fucoid-beds. Cd. Serpulite-grit. Ce I. Limestone (Ghrudaidh group). Ce II. Limestone (Eilean Dubh group). λ. Marble (Cambrian.) G. Syenite. FBo. Borolanite. F. Porphyrite Sills. T. Thrusts. T'. Moine thrust. t. Minor thrust. f. Fault.

FIG. 39.—Section from Elphin by Cnoc na Glas Choille to Allt Ealag.

A. Lewisian Gneiss. Bb. Applecross group (Torridonian). Ca. Basal Quartzite (Cambrian). Cb. Pipe-rock. Cc. Fucoid-beds. Cd. Serpulite-grit. Ce. Limestone. Ce I. Limestone (Ghrudaidh group). Ce II. Limestone (Eilean Dubh group). λ. Marble (Cambrian). FBo. Borolanite. F. Porphyrite Sills. M. Eastern Schists. T. Thrusts. T'. Moine thrust.

outline of the ground. At the base of the north-west slope of Cnoc na Sroine the altered Cambrian limestone (λ) appears not far from the nepheline-syenite (FBo), which stretches eastwards by Allt na Callagach to the plateau west of Cnoc a' Chaoruinn. On the crags near the Allt a Mhullin and in that stream itself the borolanite is well foliated—a feature which may have been produced by the post-Cambrian movements. Various outlying patches of marble (λ) occur on the moor between the stream and the outcrop of the Ben More thrust-plane. East of this line of displacement, between the road leading to Kinlochailsh and the top of Cnoc a' Chaoruinn, a constant repetition may be observed of the Cambrian zones from the pipe-rock to the basal dolomite, together with intrusive sills. The reduplication has been caused chiefly by plication, and the strata show increasing deformation as they approach the position of the Moine thrust (T'). Indeed, the alteration of the Cambrian dolomite at this locality and northwards to Loch Ailsh is so conspicuous that Mr. Callaway grouped it with his "Caledonian Series."* The last rocks on the right hand of the section (M) are a portion of the great overlying series of Eastern schists.

West of Elphin (Fig. 39) the undisturbed strata consist of Lewisian gneiss (A) overlain by the Torridon Sandstone (Applecross group, Bb) with a local basement breccia, covered unconformably by the Cambrian formation, with the zones in normal order from the basal grits (Ca) to the serpulite-grit or *Salterella* quartzite (Cd), and in places the basal dolomite (Ce). At Elphin, close to the road leading to Ullapool, the fucoid-beds and serpulite-grit with occasional lenticles of pipe-rock are truncated by a thrust that has brought forward the piled-up representatives of the *Olenellus* zone. The latter are abruptly cut off by another thrust-plane, along which the Eilean Dubh dolomites and lime-

* *Quart. Jour. Geol. Soc.*, vol. xxxix., p. 410.

stones (Ce II.), sometimes altered into marble by injections of borolanite and repeated by minor thrusts, have been driven for a distance of two miles. Throughout this tract the strata dip persistently eastwards at high angles. At Am Pollan these displaced limestones are capped by an outlier of the materials that lie upon the "sole" of the Ben More thrust, consisting of Lewisian rocks covered unconformably by the Torridon Sandstone (Bb) and basal quartzites (Ca), the latter resting unconformably on both. The westward extension of this gently-undulating dislocation and the isolation of denuded outliers of the rocks displaced by it are shown in Fig. 39 as in Fig. 38. Along their southern margin the Torridon Sandstone and basal quartzites are truncated by the Moine thrust, which, as will be mentioned below, skirts the base of the Cromalt Hills. Further east the strata are mainly composed of piled-up Eilean Dubh dolomites, marmorised in places, which, at the base of the west slope of Cnoc na Glas Choille, are overlapped by the Cambrian strata above the main outcrop of the Ben More thrust-plane. In the core of a sharp inverted arch the Lewisian gneiss is exposed by the denudation of the basal quartzites (Ca). In addition to the latter, all the Cambrian zones up to the horizon of the basement dolomite, together with several intrusive sills, have been driven westwards along this disruption plane, and have been arranged in isoclinal folds dipping eastwards at comparatively low angles. Here again a marked gradation can be traced in the metamorphism of the Cambrian sediments and the igneous sheets as they are followed eastwards to Allt Ealag, where the quartzose flagstones or Eastern schists (M) appear above the Moine thrust-plane.

At the Knockan crag, about two miles south of the village of Elphin, conclusive evidence is afforded of the remarkable overlap of the Moine thrust-plane, to which attention has already been directed. From the base of the Stack of Glencoul the course of this remarkable disruption is generally southwards by Kinlochailsh to the River Oykell and Allt Ealag, where the trend is S.S.W. It then runs west for a distance of six miles along the base of the north slope of the Cromalt Hills to the cliff about one mile S.S.W. of Knockan, passing transgressively across the Ben More thrust-plane and all underlying displaced materials till the quartzose flagstones rest directly on the undisturbed Cambrian strata (Sheet 101).

CHAPTER XXXVI.

THE STRUCTURE OF THE GROUND BETWEEN ELPHIN AND STRATH NA SHEALLAG.*

The ground to be described in this and the succeeding chapters differs in a marked degree from that which has been described in the foregoing pages. Owing to the extensive westward overlap of the Moine thrust-plane over all the lower dislocations, the belt of complicated structure has been reduced to a mere narrow stripe. No one, from the natural sections to be seen south of the county boundary between Sutherland and Ross, would suspect the existence of the extraordinary structure which is there concealed under the Eastern schists, but which, owing to extensive denudation, has been laid bare so instructively further north.

In the section shown in Fig. 40 the Lewisian gneiss appears at the western end rising from Loch Skinaskink and soon surmounted unconformably by the Torridon sandstones which form the mass of Cul Mor. The summit of that mountain is capped with an outlier of the basal quartzite, and the same member of the Cambrian series forms the eastern slopes. All these rocks retain their original relations to each other in the undisturbed ground. In the well-known Knockan cliff, which rises immediately above the road between the county boundary and Lochan Fasaidh, the pipe-rock is succeeded by the fucoid-beds, serpulite-grit, and a small portion of the basal limestone, all resting in their natural sequence and dipping south-east at 9°-12°. But no higher strata have here survived in their proper places. The Grudaidh limestone is abruptly cut off by the Elphin thrust-plane (Fig. 39), which brings forward the heaped-up white dolomites of the Eilean Dubh group. These in turn are almost immediately truncated by the micaceous schists and flagstones that lie above the Moine thrust-plane. So great has here become the overlap of this great dislocation that only a few feet of crushed marble are visible between the two thrust-planes. Even this narrow stripe soon disappears, for at the southern end of the crag the Moine thrust-plane has overlapped the Elphin thrust, and the Eastern schists (M) are thus made to rest directly upon the basal limestone. (Plate XXXVIII.) The

* The first five paragraphs of this chapter, descriptive of the ground between Elphin and Strath Kanaird, have been supplied by L. W. Hinxman; the rest is by the late W. Gunn. The district described is represented in Sheets 92 and 101 of the map of Scotland.

PLATE XXXVIII.

Outcrop of
Moine-thrust.

Outcrop of
Moine-thrust.

Moine-schists, overriding Cambrian rocks, with Olenellus Zone. Outcrop of Moine-thrust Plane shown thus (→ ←).

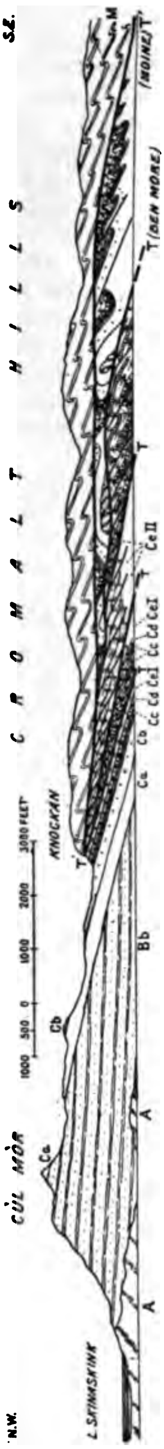

FIG. 40.—Section from Cùl Mòr, by Knockan, along the northern flank of the Cromalt Hills.

A. Lewisian Gneiss. Bb. Applecross group (Torridonian). Ca. Basal Quartzite (Cambrian). Cb. Pipe-rock. Cc. Fucoid-beds.
Cd. Serpulite-grit. Ce I. Limestone (Ghrudaidh group). Ce II. Limestone (Eilean Dubh group).
M. Eastern Schists. T. Thrusts. T'. Moine thrust.

angle of inclination of the Moine thrust is 8°-10°, in the same direction and very nearly at the same angle as that of the dip of the undisturbed beds below. There seems at first sight to be a regular passage from the Cambrian rocks up into the schists above, and this section was formerly relied upon as furnishing one of the strongest pieces of evidence in favour of such a passage. The deceptive nature of this apparent conformity is, however, soon exposed when the outcrop of the schists is followed to the north and south.

At a point about half a mile east from the Knockan road at the county boundary the Moine thrust-plane is laid bare in the bed of a tributary of Amhainn a' Chnocain, its dip being to the south at angles varying from 10° to 15°. Following the outcrop of the bare plane for half a mile we find the heaped-up masses of Cambrian limestone dipping to the east, each successive bed having been truncated by the thrust. The quartzose flagstones (Moine schists, M) dip S.S.W., south, and S.S.E. away from the plane at low angles. No more striking instance of the complete discordance between the Cambrian strata and the Eastern schists and of the plane along which the displaced materials were driven is to be found in the North-West Highlands. (Sheet 101.)

At the south end of Loch Fasaidh a cross-fault throws the thrust-plane down into a peaty hollow below the road, and when the schists are next seen, in the burn flowing out of Lochan Fada, they are found to have overlapped on to the fucoid-beds, while a little further down the burn they have been brought against the pipe-rock by a normal fault. From this point southwards to Strath Kanaird the schists and flagstones rest on different horizons of the Cambrian series, passing transgressively from basal limestone to fucoid-beds, and from fucoid-beds to limestone.

At the Strath Kanaird fault, by which the Moine thrust, as well as the underlying Cambrian strata, has been shifted up the valley to Achnacairnen, the river has laid bare a small area of Lewisian gneiss in the bottom of the valley beneath the thin capping of mica-schist. The gneiss has no doubt been brought forward upon the same thrust-plane that has borne along the much larger mass of Lewisian rock exposed by denudation nearly a mile further east at Langwell. The Langwell inlier rests upon the piled-up Cambrian beds, but at Achnacairnen these have been overlapped, and the gneiss rests directly upon the undisturbed basal limestone. Additional proof of the further overlap of this thrust and of the thinness of the cake of schistose rocks towards the outcrop of the thrust-plane, is found in the occurrence of a small lenticular area of gneiss exposed between the serpulite-grit and the thrust-plane at the roadside three-quarters of a mile north of Achendrean.

In the district between Strath Kanaird and Strath na Sheallag the belt of complication presents no marked physical features. In Strath Kanaird south of the river, where its area is increased by normal faults, it is as much as two miles broad, but for the most part less than 200 feet in height above the sea. Between this valley and that of the Ullapool River its width varies from a quarter to half a mile, and its surface rises to heights of 600 or 700 feet. In the valley below Loch Achall it widens out to as much as a mile, but in the intervening ground across to Loch Broom it never exceeds half a mile. On the west side of Loch Broom it stretches for a mile along the shore, and mounts up from sea-level to a height of about 1250 feet. To the east of Dundonnell Lodge it expands in an interesting anticline for more than a mile, but rapidly contracts to the southward until in places it is reduced to a mere narrow stripe, in which only the Moine thrust-plane can be seen. In the ground between the Strathbeg valley and Strath na Sheallag the belt reaches its highest point in this district, attaining there a height of 1500 feet.

The complexity of structure and the number of the thrusts vary considerably in different parts of this district. While, as a rule, the wider the belt the greater is its complication, occasionally, as, for example, due east of Ullapool, more thrust-planes may be observed in a width of about 300 yards than in some of the widest parts. At that place six or seven important thrusts may be counted, although generally there are not more than three. The uppermost of these is the great Moine thrust, which brings on the Eastern schists, and runs continuously through the district. Its plane dips at a less angle than those of the others, which consequently it occasionally overlaps, so as to give rise to the deceptive appearance of a regular transition from the Cambrian strata up into the Moine-schists. The other thrusts cannot be certainly identified from one part of the district to another, seeing that they cannot be traced continuously and that the material brought forward by any one thrust is not always the same.

The comparatively simple structure which prevails for nearly six miles south from Knockan ceases at Strath Kanaird, where, mainly by the more extensive denudation of the rocks above the Moine thrust-plane, but partly also by several large faults, the belt of complication has been exposed over a width of two miles. Near the hamlet of Achindrean the Torridon Sandstone is overlain in the usual unconformable relation by the lower members of the Cambrian series, which dip to the E.S.E. at an angle of about 15°, and succeed each other in their proper order up to the lowest parts of the calcareous groups. At that part of the succession the Moine thrust-plane abruptly enters and brings in the Eastern schists. Some 350 yards eastwards from the outcrop of the thrust-plane a large fault, ranging N.N.E. and with a westward downthrow of about 400 feet, brings the pipe-rock again to the surface, as may be seen here and there in a few knolls which rise out of the alluvium of the river. The quartzite is succeeded by a portion of the fucoid-beds, which are soon truncated by another north-east fault, also throwing down to the west, so as once more to expose the pipe-rock, fucoid-beds, and serpulite-grit, as well as a much thicker slice of the lower part of the limestone, which may possibly be brought on by a small thrust. Beyond these strata, one of the larger thrusts brings a slice of Lewisian gneiss above the limestone, and a little further east comes the Moine thrust. So little inclined is the plane of this dislocation here that it forms a gentle syncline filled with its characteristic schists, and emerges again at the surface not far to the east. This flat basin has been cut across by a normal N.N.E. fault, which has a displacement of about 150 feet, and shifts the outcrop of the thrust-plane. Owing to the removal of the overlying schists by denudation the same mass of Lewisian gneiss now reappears with three patches of the basal quartzite resting unconformably on its green epidositic surface. It is evident that these rocks were brought forward from a region lying to the east where no Torridon sandstone existed in Cambrian time, having either never been deposited there or having been denuded before the deposition of the quartzite. The Moine thrust-plane above this mass of gneiss was bent into an anticline, probably not a simple one, but with several minor folds, which seem to have also affected the underlying mass.

At the main bend of the stream, nearly a quarter of a mile east of Langwell, an interesting section affords a clear view of the thrust-plane. On the east side of the stream near the waterfall from beneath the flaggy Moine-schists the thrust-plane emerges, dipping eastward at an angle of 4°-5°. Immediately below the "sole" a felted breccia made up of crystalline limestone and a decomposed basic dyke lies immediately on the gneiss. In some parts of the district the number of minor thrusts is considerable, but as they often merge into one another or are overlapped by more important thrusts, sections drawn across adjacent ground but not far apart seldom resemble each other in their details.

While the ground between the Kanaird River and Loch na Maoile presents an almost bewildering succession of thrusts by which every portion of the Cambrian series has been broken up and piled together, the confusion has been increased by the constant repetition of the dislocated masses by normal faults in a north-east and an east and west direction. Some of these dislocations have a vertical throw of 500 or 600 feet. To the north of Loch na Maoile a large triangular patch of limestone, mainly belonging to the Eilean Dubh group, appears at first sight to be comparatively undisturbed, but when closely examined it is found to be one mass of thrusts, for it is studded in places with lenticular bits of various other kinds of rock, serpulite-grit, fucoid-beds, quartzite, and even a fragment of a basic dyke. The heaping-up of material by minor thrusts is well seen on either side of the outlet of Loch na Maoile. For some distance further southwards the complication becomes less, and the belt of complication narrows so much as to be in one place not more than a hundred yards in width. It broadens again to the south of the large west bay of Loch na Maoile, the greater part of its width consisting of thrust and disturbed limestone which has been pushed over the basal quartzite.* The main thrust by which all these Cambrian rocks have been driven forward coincides, for some two or three miles south of the large Strath Kanaird fault, with the upper surface of the serpulite-grit. This position may be seen on the south end of Loch Dubh, the strata not having been moved, and retaining their usual dip of 15° to the E.S.E. Immediately to the east of these rocks thrust pipe-rock may be seen inclined in the same direction at 65°, and, still further east, at 40°. To the west of Loch Ob an Lochain the highly-inclined and thrust pipe-rock is overlain by thrust serpulite-grit and fucoid-beds variously disposed, while above all comes a thrust mass of the limestone sloping down to the loch.

From Loch Dubh Beag southwards for about a mile the ground is covered with drift, so as to conceal the geology, but it is presumed that the main thrust which brings on the quartzite keeps close to the serpulite-grit, as it does in the ground to the north. The position of the Moine thrust is a little more certain, since the schists crop out in a few places. In Strath Mor, near the sources of the Allatyrne Burn, two large normal north-east faults crossing nearly at right angles repeat certain of the strata, which are thus repeated no less than four times. The structure of this interesting ground is represented in the section given in Fig. 41.

At the west end the pipe-rock (Cb) with its usual dip is succeeded in regular order by the fucoid-beds (Cc) and the serpulite-grit. The further continuous sequence of the series is interrupted here by the thrust, which brings on the quartzite (Ca). A north-east fault (f) soon brings on the fucoid-beds and

* The sloping surface of this limestone is known as Bad na h-Achlaise. Nearly all these limestone exposures form tracts of green turf, grateful to sheep and pleasing to the eye in a wilderness of rock and heather.

serpulite-grit again, now surmounted by a considerable thickness of limestone (Ce), above which lies the thrust quartzite (Ca). The thrust-plane on which this quartzite reposes dips at so low an angle that it soon overlaps the limestone, as shown by the dotted lines in Fig. 41. Where this thrust next comes to the

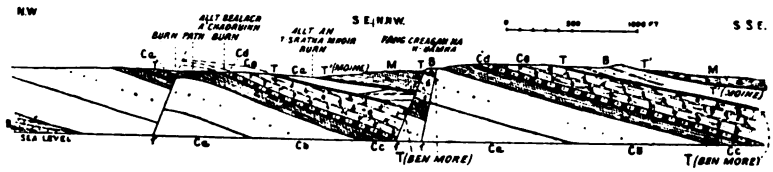

FIG. 41.—Section across upper limit of Allatyrne Burn, two miles north of Ullapool.

B. Torridon Sandstone. Ca. Basal Quartzite (Cambrian). Cb. Pipe-rock. Cc. Fucoid-beds. Cd. Serpulite-grit. Ce. Limestone. M. Eastern Schists. T. Ben More thrust. T'. Moine thrust. f. Faults.

surface it is overlain by Torridon Sandstone. In the intervening area the quartzite must rest unconformably on the sandstone, as indicated in the section. Above these rocks comes the Moine thrust (T') with its accompanying schists, which are soon truncated by a fault that trends to the south-east, and has a downthrow to the north-east of about 300 feet. This dislocation has given rise to a striking topographical feature, the elevated limestone and Torridon Sandstone forming a low crag on the south side of the dale, while the Moine-schists on the north lie on a lower plane. On the south side of the fault thrust Torridon Sandstone appears at the surface, but is quickly cut off by another large north-east fault with a downthrow to the north-west of about 400 feet. On the other side of this dislocation the upper part of the pipe-rock (Cb) is seen at the surface. Continuing on our line of section, the fucoid-beds (Cc), serpulite-grit (Cd), and limestone (Ce), with their usual E.S.E. dip, successively appear until cut off by the thrust, which here, as between the two faults, has carried forward the Torridon Sandstone (B). Not far to the south-east comes the Moine thrust (T'), together with the crystalline flaggy micaceous Eastern schists (M).

The area of thrust Torridon Sandstone here referred to broadens out eastward, so as to cover a considerable area. The inclination of its strata is eastward, generally at high angles. The southern edge of this sandstone mass is very complicated, the thrust-plane having been bent, folded, and faulted in a variety of ways, while the rocks revealed beneath it, which have been brought forward on a great sole, consist of a mixed assemblage of Cambrian strata of all kinds in which it is not easy to make out any definite arrangement. To the west in the unmoved ground the succession is perfectly normal up to the serpulite-grit, but above that horizon all is confusion. First comes a narrow strip of limestone some 150 yards in length, with a strip of fucoid-beds, which has been driven over it. Further east for more than a hundred yards the rock appears to be chiefly thrust limestone, but with slices of fucoid-beds, serpulite-grit, and quartzite. To the north of this disturbed ground the thrust Torridon Sandstone forms a feature which is conspicuous from the south side of the river. An exceptionally clear section of the thrust-plane may be seen nearly 200 yards north of the prominent crag called Creag nam Broc, and almost due west of Glastullich. It dips N.N.E. at an angle of 45° over the limestone. A little further east the thrust-plane again appears, dipping 35° east of north at angles of 40°-45°. The area of Torridon Sandstone accompanied by Lewisian gneiss bounds this complicated tract on the east and south, the plane of thrust here dipping S.S.E. at 50°-60°. In one place it overlaps all the minor thrusts, so that for some 30 yards or so the gneiss comes in contact with the serpulite-grit. The thrust again trends eastwards, and in tracing its course we soon arrive at the finest section of all, where, in the Creag nam Broc, the Torridon Sandstone lies immediately over the limestone. The plane of thrust here dips northward at an angle of 12° over the limestone, while the thrust sandstone rises above it in an overhanging cliff, so that it can be examined under the most favourable circumstances. To the east of this section the rocks above the thrust-plane have been removed by denudation, so as to lay bare the underlying limestone over a considerable area. The structure of this portion of the district is illustrated by Fig. 42.

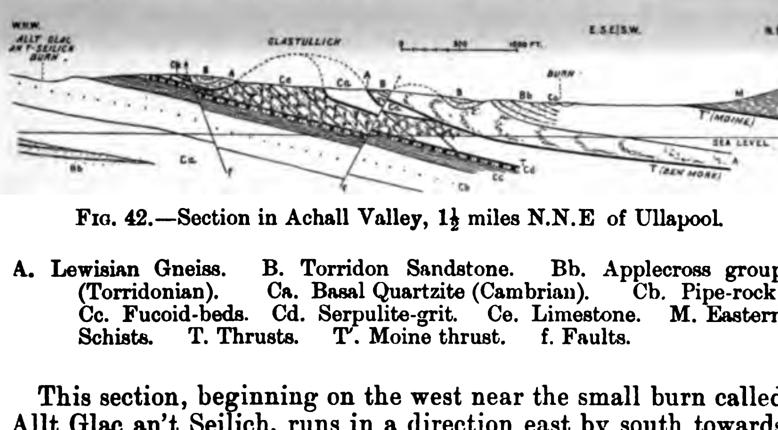

Fig. 42.—Section in Achall Valley, 1½ miles N.N.E of Ullapool.

A. Lewisian Gneiss. B. Torridon Sandstone. Bb. Applecross group (Torridonian). Ca. Basal Quartzite (Cambrian). Cb. Pipe-rock. Cc. Fucoid-beds. Cd. Serpulite-grit. Ce. Limestone. M. Eastern Schists. T. Thrusts. T'. Moine thrust. f. Faults.

This section, beginning on the west near the small burn called Allt Glac an't Seilich, runs in a direction east by south towards the outlet of Loch Achall. The pipe-rock (Cb) is here succeeded in regular order and with the usual dip to E.S.E. by the fucoid-beds and serpulite-grit (Cc and Cd). These strata are overlain by the thrust-plane, on which in the triangular area, above referred to, the limestone and other rocks have been thrust together in great confusion. Next comes a smaller thrust bringing in a slice of the pipe-rock, and then one of the larger thrusts, which has carried forward a portion of the Lewisian gneiss (A). A small fault (f) here throws down all these rocks to the east. On its further side the thrust-plane, as well as the rocks resting

on it, has been bent into a synclinal fold, in which the Torridon Sandstone (B) lies unconformably on the gneiss (A). This thrust, whereby the gneiss has been driven forward, must overlap the lower thrust, which has pushed the quartzite over the limestone. The latter member of the Cambrian series is here apparently of great thickness, with a south-easterly dip of 40° to 50°. Though the strata have probably been repeated by minor thrusts, they show no trace of the folding that has affected the overlying thrust-planes. These planes before their denudation must have arched over the limestone somewhat in the manner represented by the dotted lines in the section. On the east side of the anticline the quartzite lying on its thrust-plane is overlain in turn by the higher dislocation, which once more brings in view the gneiss with its covering of unconformable Torridon Sandstone. Owing to a small normal north-easterly fault the gneiss again appears at the surface until further east it passes finally under the Torridon Sandstone (Bb). Some patches of the basal quartzite (Ca) which have survived on the surface of the sandstone not only illustrate the double unconformability of the Torridon series on the Lewisian gneiss and of the Cambrian quartzite on the Torridonian Sandstone, but indicate that the latter rock has been driven forward from some now concealed eastern area where its thickness is not great. The thrust rocks of Strath Kanaird prove that no Torridon Sandstone existed at that place in Cambrian time, for the quartzite rests there immediately on the Lewisian gneiss. Beyond some obscure ground the section reaches the Moine thrust and enters the region of the Eastern schists (M).

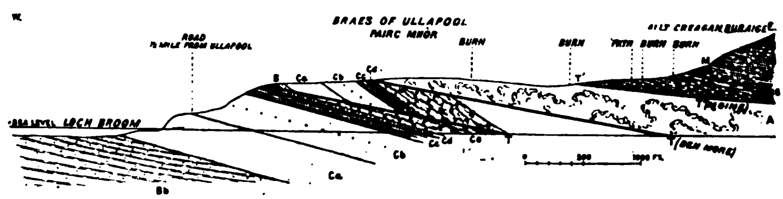

FIG. 43.—Section from Loch Broom across the Braes of Ullapool to Allt Creagan Buraige.

A. Lewisian Gneiss. B. Torridon Sandstone. Bb. Applecross group (Torridonian). Ca. Basal Quartzite (Cambrian). Cb. Pipe-rock. Cc. Fucoid-beds. Cd. Serpulite-grit. Ce. Limestone. M. Eastern Schists. G. Intrusive Igneous Rock in Moine-schist. T. Thrusts. T'. Moine thrust.

The section represented in Fig. 43 runs parallel to that in Fig. 42 at a distance to the south of rather more than a quarter of a mile. It starts in the basal quartzite at the level of Loch Broom, about 100 yards south of the marked bend in the road that occurs half a mile south-east of the Royal Hotel. The basal quartzite, pipe-rock, fucoid-beds, and serpulite-grit lie here on the Torridon Sandstone quite undisturbed, and showing the usual dip to the E.S.E. of about 15°. Immediately above them, however, a thrust has driven forward a strip of Torridon Sandstone, followed by the quartzite (Ca, Cb) and succeeding members of the Cambrian series, dipping to the east at 30°-40°. Above the top of the fucoid-beds, however, comes the Lewisian gneiss, though the serpulite-grit (Cd) and limestone (Ce) probably supervene in their proper order underneath the thrust-plane, as represented in the section. The exact place of the Moine thrust cannot here be fixed, as the ground is obscured with drift, but in the higher ground the Eastern schists (M) come on with their usual flaggy character and low easterly dip of 10°-15°.

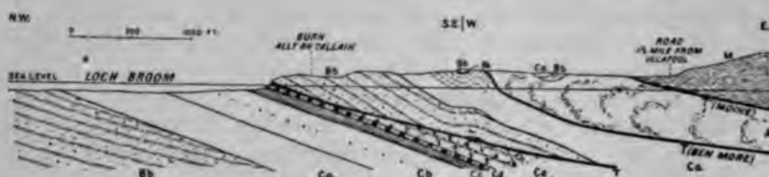

FIG. 44.—Section from Loch Broom, 350 yards north from Corry Point, eastward to beyond High Road.

A. Lewisian Gneiss. Bb. Applecross group (Torridonian). Ca. Basal Quartzite (Cambrian). Cb. Pipe-rock. Cc. Fucoid-beds. Cd. Serpulite-grit. Ce. Limestone. M. Eastern Schists. T. Thrusts. T'. Moine thrust.

A section drawn about a mile further south than the last shows the structure represented in Fig. 44. The Torridon Sandstone, basal quartzite, pipe-rock, and fucoid-beds are here concealed under the waters of the loch. The serpulite-grit, however, is seen, followed by some 15 to 20 feet of a whitish limestone, above which a thick mass of Torridon Sandstone (Bb) has been driven by a thrust, of which the plane dips to the south-east at 25°-30°. The lower part of the sandstone, which is coarse, has been drawn out, and is crushed or mylonised, its usual pinkish or brown colour being changed to green. Further east the sandstone is overlain with quartzite (Ca), the line of junction being possibly a slight thrust. The whole of these thrust rocks have been so disturbed and contorted that it is not easy to estimate their thickness. As in the previous sections, a mass of Lewisian gneiss (A) with patches of Torridon Sandstone resting on it has been driven over the quartzite. In places the plane of the thrust by which this displacement has been produced dips at a gentle angle, while in others it has been thrown into a series of rather sharp folds, so that its outcrop at the surface is very irregular. In several places near the edge of the thrust-plane the normal positions of the Torridon Sandstone and the gneiss are reversed, and the former appears to dip under the latter at a high angle, as on the eastern side of an anticline which bounds the quartzite, where the younger formation dips under the older at angles of 30°-45°. A little to the west of the road the Moine thrust is met with, followed as usual by the schists (M), which it introduces. These schists, dipping eastwards at a gentle angle but occasionally crumpled, are well exposed at the head of the bay of Loch Broom, called Camas an Daimh. They are underlain immediately to the west by a crushed rock, not improbably Torridon Sandstone, and then by the granitoid gneiss, which now comes on in force for a distance of 500 yards along the shore as a massive acid rock that offers a marked contrast in character to the flaggy Moine-schists.

The belt of complication in its southward course now passes under the waters of Loch Broom. On the south-western side of this inlet of the sea it is found considerably to the south, the Moine thrust, for example, being about a mile to the south of its position where last seen on the opposite side. The plane of this thrust crops out opposite to Leckmelm House, and dips to the E.S.E. at 10° over much-altered Torridon Sandstone. It is immediately surmounted by the usual flaggy, grey quartzo-micaceous schists. The outcrop of the thrust-plane trends at first westwards, and then north of west for nearly a mile and a half altogether, rising gradually to over a thousand feet above the sea, and in the western part of its course forms a fine topographical feature. The gentle south-easterly dip of this plane or "sole" exactly coincides in some places with the slope of the ground. Only one other thrust makes its appearance here; it is probably the continuation of that which brings on the Lewisian gneiss and patches of Torridon Sandstone to the east of Corry Point on the opposite side of the loch. On the shore its position is at first hidden by the raised beach of Newton Loggie, but it comes into sight west of the rocky knoll on which stand the ruins of the old Pictish tower called Dun Lagaidh. The plane of this thrust seems for a long distance to keep an even surface at the top of the serpulite-grit, over which comes a mass of Lewisian gneiss, covered with many unconformable patches of Torridon Sandstone. The gneiss continues to be the rock immediately resting on the sole of the thrust as far south as a little beyond Loch Lagaidh. The overlying Torridon Sandstone, much altered and with its bedding generally confused, now comes to lie on the thrust-plane for a quarter of a mile as a band not more than 70 or 80 yards broad. The gneiss soon reappears, however, for a short distance next to the thrust-plane until the sandstone resumes its place between that plane and the much-disturbed Cambrian strata.

The most remarkable feature along this part of the belt of complication is to be observed on the slopes of the great ridge that rises to the east of Dundonnell Lodge, where, as shown on Sheet 92, an anticlinal loop of the thrust rocks strikes eastwards for about a mile, while the main mass of the Torridon Sandstone and of the Cambrian rocks that lie immediately to the westward have been unaffected by this plication. The outcrop of the Moine thrust-plane bends eastward on the north of this fold to return again on the south side, and resume thereafter its usual southerly direction. But this singular disturbance is not confined to the rocks that underlie the thrust-plane. It continues in the crystalline schists, which are found to be vertical or nearly so, right across the whole ridge eastward through Cnoc an Droighinn to the edge of Loch Broom. Not only so, but on the opposite side of the loch high dips also prevail among the Eastern schists on this line of complication for a long way to the east. Although much of the ground is obscured by peat and drift, enough of rock is exposed at the surface to afford a probable clue to the general structure of this portion of the complicated belt. The section in Fig. 45 explains what is believed to be the arrangement of the rocks here. It is drawn from a point on the Ullapool road in a south-easterly direction up the steep slope and across a portion of the plateau above.

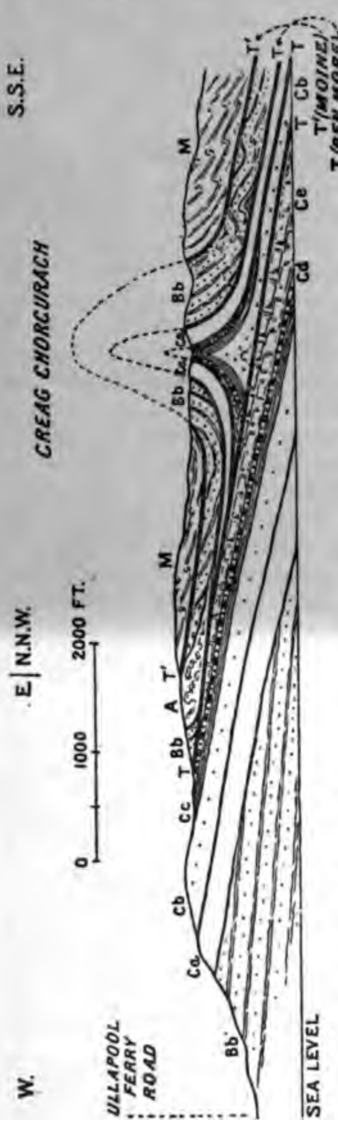

Fig. 45.—Section across Anticline near Creag Chorcurach, 1 mile east from Dundonnell Lodge, Little Loch Broom.

A. Lewisian Gneiss. Bb. Applecross group (Torridonian). Ca. Basal Quartzite (Cambrian). Cb. Pipe-rock. Cc. Fucoid-beds. Cd. Serpulite-grit. Ce. Limestone. M. Eastern Schists. T. Thrusts. T'. Moine thrust.

The Torridon Sandstone and the overlying unconformable Cambrian strata are here lying undisturbed in their normal position. Some slight displacements begin to be observable in the fucoid-beds, and the dip of these strata rises to 20° or 30°. Eventually, however, after several minor thrusts and repetitions, the lower part of the limestone (Ce) makes its appearance, only to be immediately truncated by the thrust which brings up the Torridon Sandstone, much crushed and otherwise altered, and veined with strings of quartz with a core of Lewisian gneiss in its midst. Then follows the great Moine thrust (T′) with its accompanying flaggy schists. Up to this point the section merely repeats the sequence of rocks seen further north. But on the plateau a little further to the south-east the anticlinal fold abruptly makes its appearance. Along the western part of the axis of this fold an almost continuous outcrop of the fucoid-beds can be followed for a distance of about 650 yards. These strata are everywhere vertical, and probably their whole thickness may be represented here on each side of the axis, as the breadth of their double outcrop is in some places nearly 150 feet. About 150 yards to the north-east of the Ordnance station (Δ 1193) on Creag Chorcurach (Sheet 92) a small exposure of serpulite-grit on the south side of the axis leads to the presumption that this rock overlies the fucoid-beds. A strip of thrust quartzite (Ca) probably runs along both sides of the anticline, flanked by Torridon Sandstone (Bb) as a continuous band connected with the tract to the north and running all round the flanks of the anticline. As the sandstone from its position on the north side of the fold must obviously overlie the quartzite there, it has evidently been brought into that position by a thrust. The quartzite in like manner must have been driven over the serpulite-grit. The "soles" of these several thrusts have been ridged up together with the strata between them, and now appear folded in anticlinal form as if they had been original stratification-planes. Moreover, it is evident that all these rocks have been brought forward on a thrust-plane which has not been affected by the anticlinal folding, seeing that the quartzite and Torridon Sandstone lying to the west have remained undisturbed.

The actual outcrop of the Moine thrust-plane is obscured on both sides of the anticline. On the south side the Torridon Sandstone, here a light-coloured siliceous grit, sometimes a conglomerate, has been rendered so schistose as at first sight to be barely recognisable. Traced further to the south-east it assumes a more and more altered condition until it becomes so like the flaggy Eastern schists near the Moine thrust that the two groups of rock can hardly be distinguished from each other. To the east of the Ordnance station on Creag Chorcurach occasional bands of a coarse gritty schist or crushed gneiss alternate with bands of finer grain like the Moine-schists. Whether or not the whole of this material should be regarded as altered Torridon Sandstone and Lewisian gneiss remains undecided.

Along the course of the belt of complicated structure for a long distance southwards the pipe-rock is not followed by any of the later members of the Cambrian series, but by a thrust-plane on which rests a thick mass of siliceous mylonite, forming the under part of the crop east of Dundonnell House and the ground further south. The next rock visible is the flaggy Moine-schist, but the boundary between it and the underlying mylonite is ill-defined. The two rocks seem to graduate into each other as in other places in the districts to the north. The mylonite may not improbably be composed not only of the crushed and rolled-out members of the Cambrian series and the Torridon Sandstone, but also of crushed crystalline-schist.

So greatly does the belt of complication contract in width as it goes southward that for some distance there may possibly be no recognisable thrust rock at all at the surface. From an examination of the rocks in Strath Beg alone one could hardly come to any other conclusion than that the Moine-schists overlie the Cambrian rocks conformably as was formerly believed. Rather more than a mile further south the serpulite-grit once more shows itself, with a strip of deformed quartzite thrust between it and the Eastern schists. The fucoid-beds likewise make their appearance, but much dislocated and displaced. The whole of the rocks here have been greatly disturbed. They pass under a mass of thrust Torridon Sandstone, which, as usual in this district, has been much deformed by pressure and is full of quartz-veins. This mass is truncated by the Moine thrust-plane, which lies nearly flat or gently undulating, and supports the Eastern schists. As the foliation-planes of these schists are inclined at a considerable angle, they must abut against the sole of the thrust. The foliation-planes certainly coincide here with those of stratification, for they separate bands that distinctly differ from each other in lithological composition.

CHAPTER XXXVII.

STRUCTURE OF THE GROUND FROM STRATH NA SHEALLAG BY LOCH MAREE TO AUCHNASHELLACH.*

In the tract to be described in the present chapter the complicated structure of the North-West Highlands attains a development comparable to that so well displayed in Assynt (Chapter XXXV.). In the northern portion of the district within the Dundonnell Forest, as in the ground described in the last chapter, the complicated belt lying to the west of the Moine thrust is only about a quarter of a mile broad, but further south around the head of Loch Maree its width increases to some three miles, and in the Auchnashellach Forest to four miles. Moreover, in the northern tract the visible structure is comparatively simple, owing partly to the narrowness of the belt of complication and partly to the absence of imbricate structure in advance of the Ben More thrust on Mullach Coire Mhic Fhearchair. (Fig. 47.) Southwards, however, between the Heights of Kinlochewe and Auchnashellach striking proofs are displayed (1) of the reduplication of the strata over miles of ground by inverted folds and minor reversed faults in advance of the powerful lines of disruption, (2) of the folding and faulting of the great thrust-planes, (3) of the formation of a large outlier of displaced materials overlying the Kinlochewe thrust-plane, and (4) of the deformation of the Torridon Sandstone to the west of the Moine-schists in the neighbourhood of Coulin south of Kinlochewe. In the following description of this district, the Kinlochewe thrust is regarded as the equivalent of the Ben More thrust in Assynt and of the Kishorn displacement near Stromeferry.

The narrowness of the belt of complication in Strath na Sheallag and southwards in the direction of Loch an Nid is illustrated by the accompanying section (Fig. 46), visible in a small stream on the eastern side of the valley, which joins the Loch an Nid River about half a mile east of Achneigie. Above the point where the tributary enters the alluvium of the main valley an ascending sequence of undisturbed Cambrian strata

* This chapter has been prepared by B. N. Peach and J. Horne, with notes from E. Greenly. The district described is comprised in Sheets 82 and 92 of the map of Scotland, on the scale of 1 inch to a mile ($\frac{1}{63360}$).

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can be followed from the basal quartzites (Ca) to the fucoid-beds and serpulite-grit (Cd). Just above the point where the burn is crossed by the hill-road leading to Dundonnell, the upper portion of the fucoid-beds (Cc) is exposed, together with the bands of dark-blue shale (Cc′), which first yielded the *Olenellus* fauna. The normal succession of strata is here interrupted by a powerful thrust (Ben More and Kinlochewe) which has brought forward a thin wedge of Torridon Sandstone (B), considerably

FIG. 46.—Section in Allt Righ Iain, Strath-na-Sheallag, Dundonnell Forest.

A. Lewisian Gneiss. B. Torridon Sandstone. Ca. Basal Quartzite (Cambrian). Cb. Pipe-rock. Cc. Fucoid-beds. Cc′. *Olenellus* Band. Cd. Serpulite-grit. Ce. Limestone. M. Eastern Schists. T. Ben More thrust. T′. Moine thrust.

crushed, of a greyish tint. Not far to the east the sandstone is abruptly truncated by the Moine thrust (T′) and Eastern schists, the line of disruption being clearly displayed on the banks of the stream. When traced southwards in the direction of Loch an Nid this slice of Torridon Sandstone increases in thickness, and is seen to rest unconformably on Lewisian rocks (A), the materials having been driven westwards along the Ben More thrust-plane, the outcrop of which can be easily traced for about a mile on the prominent crag on the east side of the valley. (Sheet 92.)

The relations of the strata at Loch an Nid and in the mountainous ground to the west are shown in the section given in Fig. 47. The western part of this section, beyond the belt of complication, illustrates how uneven was the land-surface on which the Torridonian sediments were laid down. On the western slope of Mullach Coire Mhic Fhearchair these sandstones and grits (Bb), which reach there a thickness of about 2000 feet, can be seen to have been accumulated around and above hills of Lewisian gneiss that rise to a height of 1000 feet, and are now gradually being uncovered in the progress of denudation. Above this pile of sediment the Cambrian quartzites (Ca) rest unconformably on the eroded edges of the Torridon Sandstone, followed in order by the pipe-rock (Cb), the fucoid-beds (Cc), serpulite-grit (Cd), and a few feet of the basal dolomite (Ce). At this point in the Cambrian series the undisturbed strata are abruptly truncated by the Kinlochewe thrust, which has brought westwards a cake of Lewisian basic and acid gneisses traversed by epidiorite dykes (B^a). These rocks (A) rest on the

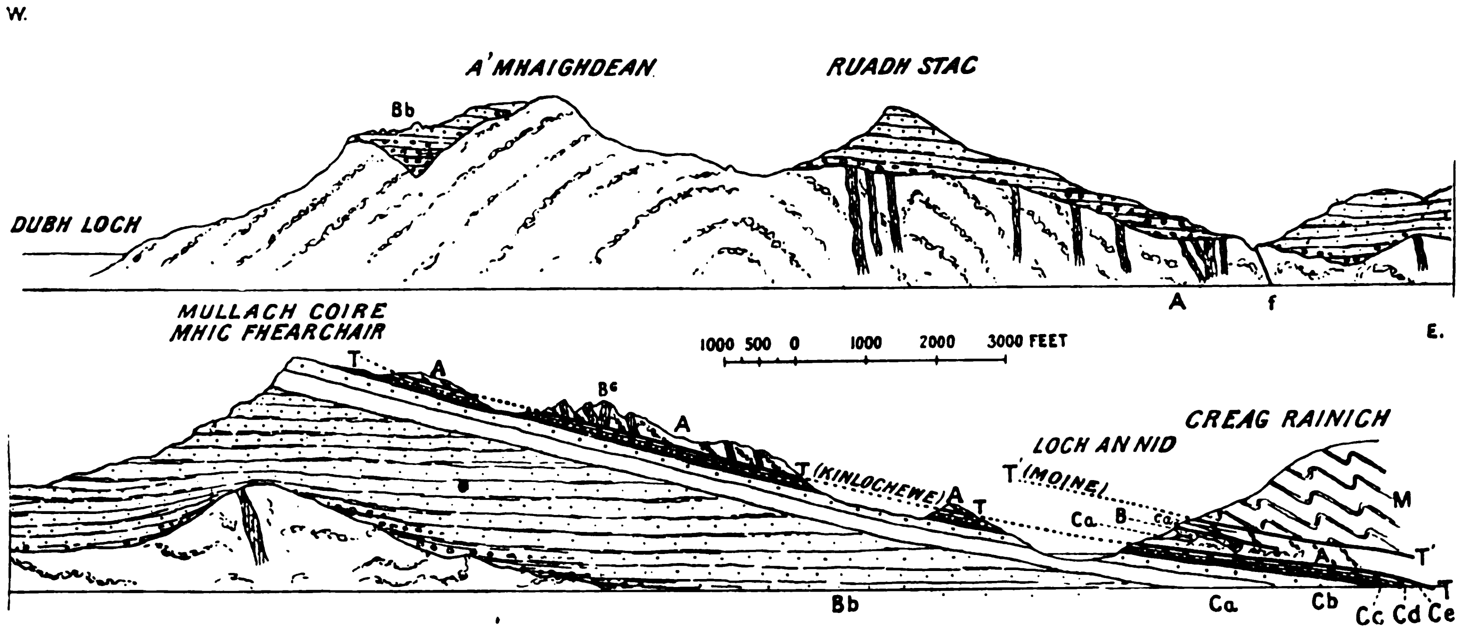

FIG. 47.—Section from A' Mhaighdean by Mullach Coire Mhic Fhearchair to Creag Rainich.

A. Lewisian Gneiss. Bᴳ. Dykes in Gneiss. B. Torridon Sandstone. Bb. Applecross group (Torridonian). Ca. Basal Quartzite (Cambrian). Cb. Pipe rock. Cc. Fucoid-beds. Cd. Serpulite-grit. Ce. Limestone. M. Moine-schists. T. Kinlochewe thrust. T'. Moine thrust. f. Fault.

inclined thrust-plane (T), and form a serrated ridge on the eastern slope of the mountain. Several minor thrusts or reversed faults, not shown in the figure, affect the course of the dykes. On the west side of the Loch an Nid valley, on the dip slope of Sgurr Ban, a small patch of gneiss, which has been isolated by denudation from the thrust mass on Mullach Coire Mhic Fhearchair, is named Meallan an Laoigh (the calf hillock). The fucoid-beds and serpulite-grit can be traced round this outlier, and the basal dolomite appears on its western side, truncated in like manner by the Kinlochewe thrust. (Sheet 92 and Fig. 47.) No trace, however, can here be seen of any imbricate structure beneath the slice of Lewisian rocks. The remarkable piling-up of the Cambrian strata in advance of the displaced gneiss, so conspicuous in Eireboll and Assynt, is entirely absent.

East of Loch an Nid a normal sequence of undisturbed Cambrian rocks is traceable from the pipe-rock to the basal dolomite, above which the rest of the Cambrian series has been displaced, as on the west side of the valley, by the Kinlochewe thrust. The Lewisian rocks which now supervene are overlain by the Torridon Sandstone (B), with the basal quartzite (Ca) resting unconformably on both.

Not far to the north of this line of section the conglomerate at the base of the Torridon Sandstone lies in visible contact with the displaced gneiss. It is here a coarse deposit, its pebbles ranging from seven inches to a foot across, and consisting of felsite, jasper, quartz, and altered purple quartzite, with fragments of acid and basic gneiss. It is worthy of note that these pebbles are not deformed nor is the matrix schistose, as is the case with the same conglomerate above the Ben More thrust-plane in the Oykell valley, Assynt. The overlying purple and grey grits and shales have likewise escaped extreme deformation; they are not schistose, but merely crushed and traversed by a network of quartz-veins. Above these displaced materials, thrust fucoid-beds and serpulite-grit, together with a thin wedge of Lewisian gneiss, are abruptly truncated by the line of disruption that has driven westward the granulitic schists of the Moine series (M).

From the ground traversed by the line of section in Fig. 47 southwards to the Heights of Kinlochewe and Beinn a' Mhuinidh the width of the area of displaced gneiss lying between the Kinlochewe and Moine thrust-planes gradually increases to three miles (Sheet 92), and presents many of the normal characters of the Fundamental Complex and of the later basic dykes to the west. Here as elsewhere the deformation of the Lewisian rocks between these great lines of disruption is more or less confined to certain zones near the thrust-planes. On the surface of this extensive plateau of displaced Lewisian rocks small isolated patches of Torridon Sandstone occur, as shown on the map. Thus, about half a mile east of Lochan Fada beyond the head of Gleann na Muice, the basal breccia is seen to rest unconformably on the old floor, followed by shales, but the strata are here highly contorted and inverted. Further to the north-east on the western slopes of Beinn Bheag and close to the outcrop of the Moine thrust-plane, the double unconformability of the Cambrian quartzite on the Torridon Sandstone and Lewisian gneiss is visible.

The outcrop of the Kinlochewe thrust-plane, which bounds the displaced Lewisian rocks on the west, is here well defined. To the north-east of Lochan Fada it has been shifted for about a mile to the south-west by the Fasagh fault. It then passes southwards along the conspicuous escarpment west of Beinn a' Mhuinidh to the Kinlochewe River. At the Heights of Kinlochewe evidence has been observed of an intermediate displacement in advance of the Moine thrust, accompanied by marked deformation. A triangular mass of highly-sheared gneiss here displays a narrow infold of Torridon Sandstone and shales (Diabaig group), traceable along the east side of Gleann na Muice for three-quarters of a mile. These sediments have been rendered schistose, an alteration specially apparent in the grits. The deformed gneiss and Torridon Sandstone have been driven westwards along a plane that runs up Gleann na Muice and truncates the underlying Lewisian gneiss with its basic dykes.

Over a great part of the area between Loch an Nid and the Heights of Kinlochewe the exact position of the Moine thrust can with difficulty be fixed, owing partly to the absence of sections in the direction of the dip of the strata, and partly to the mylonised rocks which so often accompany this great line of displacement. These mylonised materials have resulted from the shearing of gneiss and green epidotic grits. They are well developed near Loch a' Mheallain Odhair, two and a half miles north of the Heights of Kinlochewe, and also on the western slope of Sron Dubh. But on the south-west declivity of Beinn Bheag, and particularly in the valley of Abhuinn Bruachaig below the Heights of Kinlochewe, the Moine thrust is clearly traceable. Indeed, in the latter area, where the ground is bare of drift, the Eastern schists above that plane of disruption pass transgressively across the displaced Lewisian gneiss and the Torridon Sandstone with a small patch of the basal quartzites. At the Heights of Kinlochewe the thrust-plane is shifted westwards for about half a mile by an E.N.E. and W.S.W. fault.

Beyond the Heights of Kinlochewe the structure of the country becomes remarkably complicated. A conspicuous example of this complexity may be seen on the rocky ridge on the north side of the Kinlochewe River (Fig. 48), where, owing to the inversion of the displaced materials, the folding of the Kinlochewe (Ben More) thrust-plane, and the subsequent denudation of the rocks overlying that plane, the structure has been found most difficult to unravel. The western part of this section supplies another illustration of the uneven land-surface on which the Torridon Sandstone reposes, the ridge of Meall Riabhach being flanked by pre-Torridonian valleys on either side. In Gleann Bianasdail the position of the Fasagh fault (f) is

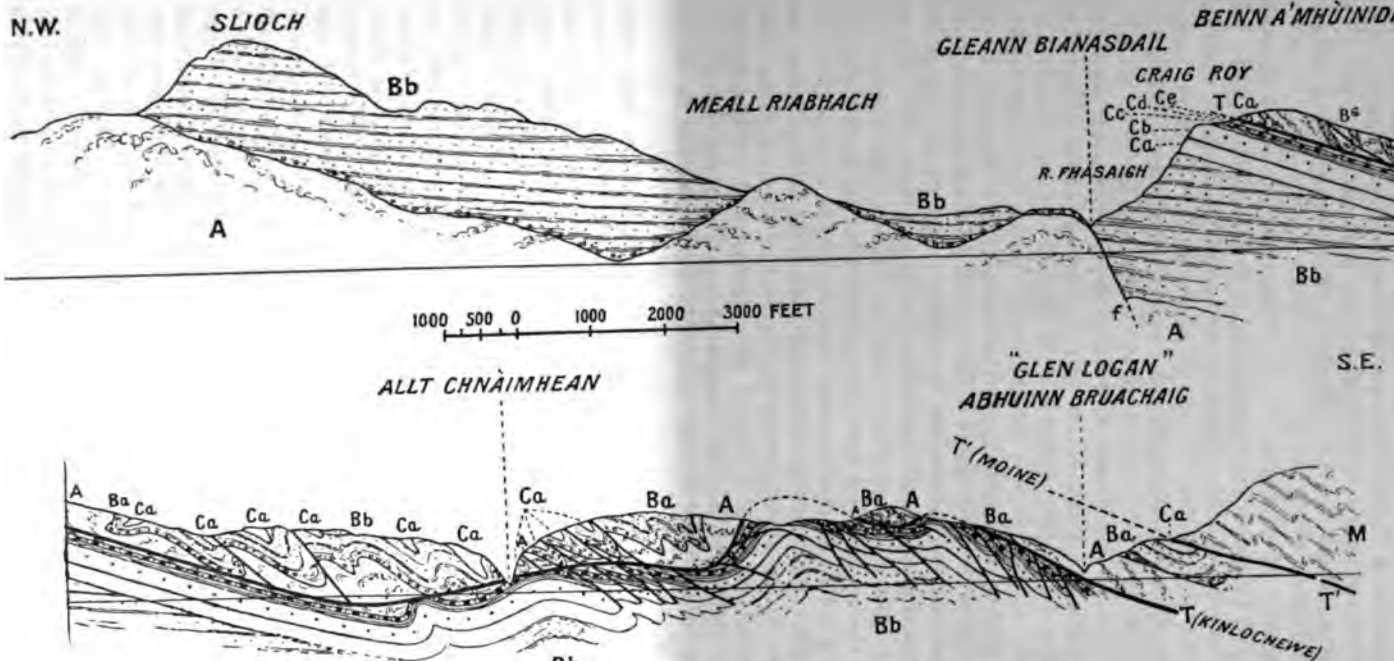

FIG. 48.—Section from Siloch by Beinn a' Mhùinidh to Abhuinn Bruachaig.

A. Lewisian Gneiss. Bᵃ Dykes in Gneiss. Ba. Diabaig group (Torridonian). Bb. Applecross group. Ca. Basal Quartzite (Cambrian). Cb. Pipe-rock. Cc. Fucoid-beds. Cd. Serpulite-grit. Ce. Limestone. M. Eastern Schists. T. Thrusts. T'. Moine thrust. f. Fault.

shown, whereby the Torridon Sandstone on the east side of the valley is let down against the hornblende-schists of Lewisian age to the west. Along the eastern slope of this valley runs the unconformable junction between the Cambrian quartzites (Ca, Cb) and underlying red sandstones (Bb). A normal sequence can here be followed from the basal quartzites to the representatives of the *Olenellus* zone (the Middle Series), and in places to the basal dolomite (Ce).

On Craig Roy the succession is interrupted by the Kinlochewe (Ben More and Kishorn) thrust-plane (T), above which appear the Lewisian rocks (A) with an infold of the basal quartzite (Ca), the unconformable junction between the two rocks being well exposed. Eastwards across the slope the Lewisian plateau is traversed by lines of movement producing no marked deformation. About half a mile to the south of the top of Beinn a' Mhuinidh the Lewisian rocks are covered unconformably by the Torridon Sandstone (Ba), with infolds of the basal quartzite, arranged in isoclinal folds. The axial planes of these folds are inclined generally to the E.S.E., and are truncated in places by minor thrusts hading in the same direction. These red sandstones stretch eastwards from Meallan Gobhar to the hills beyond Allt Chnaimhean (the burn of the bones), and cover more than a square mile of ground. Along their northern margin their unconformable boundary-line with the gneiss has been traced (Sheet 92), and they are there found to be usually inverted and to pass underneath the older formation. The basal breccia at the line of junction contains fragments of the underlying gneiss.

The gorge in the lower part of Allt Chnaimhean has been cut by the stream through the overlying cake of thrust Lewisian rocks, Torridon Sandstone, and basal quartzite, so as to reveal the piled-up fucoid-beds, serpulite-grit, and basal dolomite beneath the Kinlochewe thrust-plane (T). The exposure of these successive layers of displaced materials is due not only to denudation, but partly also to the folding of the rocks above and below this line of displacement, as represented in Fig. 48. A still more striking example of this complicated structure occurs about half a mile to the east of Allt Chnaimhean, where the thrust-plane, together with the rocks which it separates, has been sharply folded, and where the thin veneer of gneiss and red sandstone overlying the thrust-plane has been removed from the crest of the arch. The dome-shaped arrangement of the Cambrian strata beneath that plane is well seen on the hill-top and southern slope facing the road that leads to Kinlochewe. The third sub-division of the pipe-rock is the lowest Cambrian zone here represented. It is followed by the higher sub-zones, the fucoid-beds, and serpulite-grit, which are repeated by reversed faults. Further east, owing to a minor fold, a lobe of the displaced materials which lies above the Kinlochewe thrust-plane consists of gneiss with an infold of the red sandstone. Although represented as an outlier in Fig. 48, it is really connected with the main mass. On the slope towards Abhuinn

Bruachaig the bare plane of the Kinlochewe thrust is exposed, and for part of the distance the Lewisian gneiss rests mainly on the Cambrian limestone. Here, too, the inverted junction of the Torridon Sandstone (Ba) with the gneiss (A) above the line of displacement is visible, while to the south of the outcrop of the thrust-plane the repetition of the fucoid-beds, serpulite-grit, and basal dolomite is clearly observable.

In the channel of Abhuinn Bruachaig (or "Glen Logan"), about two miles up the valley from Kinlochewe, the same important line of disruption is laid bare, where pink epidotic granitoid gneiss ("Logan Rock" of Heddle) is superimposed on the dolomite of the Ghrudaidh group, the upper serpulite-band being visible within a few yards of the plane. Close by are the fucoid-beds, which have yielded fragments of *Olenellus*. Further down the stream the gneiss, exposed in several places, is associated with a mass of crushed Torridon Sandstone (Ba) in the triangular space between the Abhuinn Bruachaig and Glen Docherty. At one locality, as shown in Fig. 48, the crushed sandstone is succeeded by the basal quartzite (Ca) beneath the Moine thrust-plane (T′).

Reference has already been made to the correct identification by Professor Bonney of the Lewisian gneiss and Torridon Sandstone in Abhuinn Bruachaig (Glen Logan), and to the recognition of the reversed fault whereby the gneiss has been brought to the surface.

The horizontal section in Fig. 48 shows that the materials above and below the Kinlochewe thrust-plane, together with that plane itself, have been thrown into a compound anticline and syncline, and that the folding was developed subsequent to the thrusting.

Before describing the effects of the great fault that runs along Loch Maree and up the valley of Glen Docherty, whereby the undisturbed strata, the successive thrust-planes, and the displaced masses have been shifted westwards on the south side of the dislocation, it will be desirable to indicate the relations of the strata on the south side of the Kinlochewe River and the head of Loch Maree.

Along the south-west side of Loch Maree, in the undisturbed Torridon Sandstone in Glen Grudie (Sheet 92), we find the prolongation of the Fasagh fault, which has been shifted about three miles to the west of its position in the Fasagh Glen at the head of the loch. On the eastern slope of Glen Grudie (as shown in Fig. 49) undisturbed Cambrian strata, ranging from the basal quartzites to the serpulite-grit (Ca to Cd), and in places to the basal limestone, dip in an easterly direction at angles varying from 10° to 20°. These undisturbed strata are abruptly truncated by the Kinlochewe thrust, and are overlain by a large mass of Torridon Sandstone (Ba, Bb) with inliers of Lewisian gneiss (A), which together cover an area of a square mile and a half round Meall a' Ghiubhais. This prominent hill (2882 feet), about two miles to the west of the head of Loch

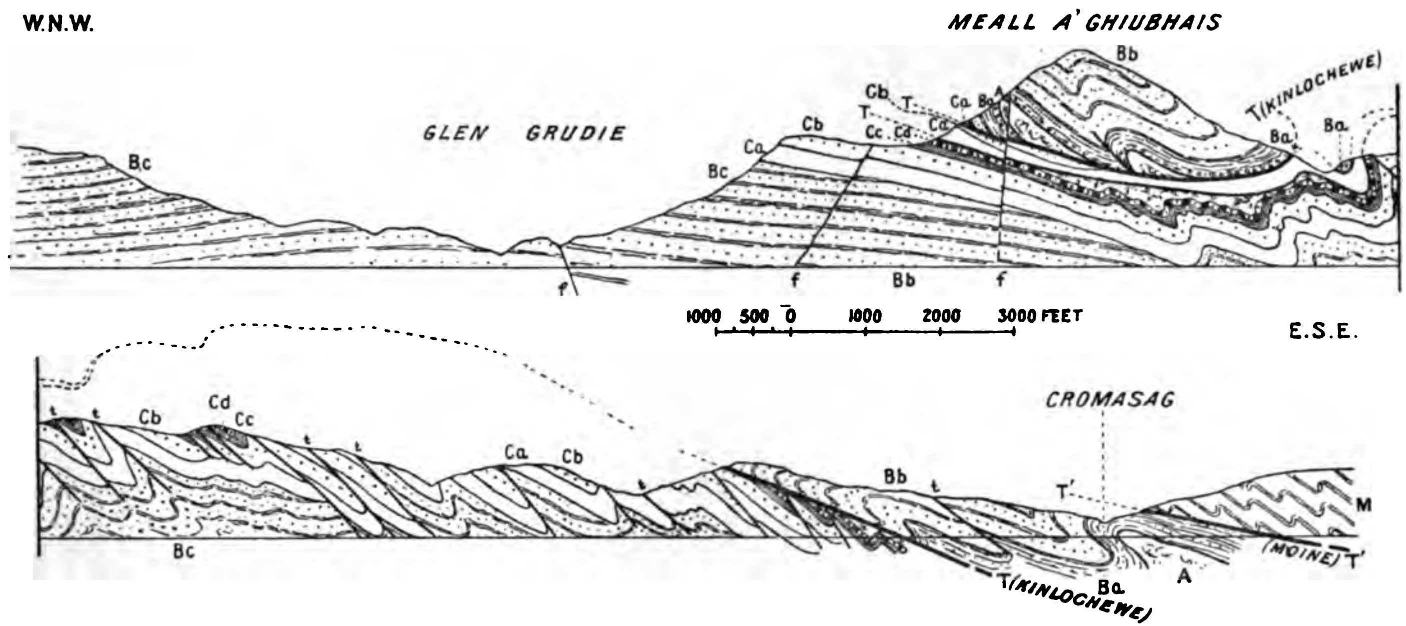

FIG. 49.—Section from Glen Grudie by Meall a' Ghiubhais to Cromasag, south of Kinlochewe.

A. Lewisian Gneiss. Ba. Diabaig group (Torridonian). Bb. Applecross group. Bc. Aultbea group. Ca. Basal Quartzite (Cambrian). Cb. Pipe-rock. Cc. Fucoid-beds. Cd. Serpulite-grit. M. Eastern Schists. T. Thrusts. T'. Moine thrust. t. Minor thrusts. f. Normal faults.

Maree, forms a conspicuous outlier of displaced materials. The thrust-plane on which these materials lie can be traced round the mountain, where it appears as a circular fault or line of discordance between the rock masses. While the Torridon Sandstone rests on undisturbed Cambrian strata on the north and north-west, a slice of basal quartzite and pipe-rock, which has been driven westwards by an intermediate minor thrust, comes beneath the thrust-plane on the south and east, and is recognisable from a distance owing to the white fringe which the strata form beneath the darker overlying sandstone. In this outlier the Diabaig and Applecross groups of the Torridon Sandstone are both represented, the strata being arranged generally in the form of a syncline with a compound anticline towards the west. They rest on the gneiss, which, as shown in Fig. 49, appears in places between them and the thrust-plane. On the west side of the mountain, near the base of the red sandstones, a portion of the basal quartzite (Ca) has been infolded with the Diabaig beds. The strata are here not much deformed, save near the thrust-plane and the other minor displacements. Where the arkose has become slightly schistose, the dark and grey shales have been cleaved, and along the actual lines of movement the strata have been transformed into flinty crush-rocks. A small patch of displaced Torridon Sandstone which lies to the east of the main outlier on Meall a' Ghiubhais rests partly on basal quartzite and partly on serpulite-grit.

Eastwards for a distance of two miles the Cambrian zones up to the serpulite-grit are repeated by inverted folds and reversed faults, their general inclination being towards E.S.E. and E. The underlying Torridon Sandstone has shared in these plications, for, on the wooded slopes facing Loch Maree and in the cliff above, the members of that system, not much deformed, can be seen to rise from underneath the quartzite in great flexures, and along the line of section (Fig. 49) in sharp isoclinal folds.

About three-quarters of a mile west of Cromasag (Sheet 82) the main outcrop of the Ben More thrust-plane appears, where the Torridon Sandstone is superimposed on the lowest sub-zone of the pipe-rock. In that stream the beds of arkose (Applecross group, Bb) dip to the south-east at angles ranging from 35°-45°, with little trace of schistosity, but traversed by numerous veins of quartz. Flaser-structure, which begins to appear in the grits on the west side of the valley, not far from the Kinlochewe Hotel, is finely developed among these rocks in the bed of the Kinlochewe River south of Cromasag, close to the Moine thrust-plane. This line of disruption is here concealed by alluvium, but the green schists which overlie it are exposed in the river not far to the north and south of Cromasag.

A comparison of the structures on either side of the valley below Glen Docherty, as revealed in the foregoing sections (Figs. 48 and 49), will show the great horizontal displacement produced by the fault which runs along the length of Loch Maree. It will be seen that (1) the Fasagh dislocation has been shifted three miles to the west to Glen Grudie; that (2) the outcrop of the undisturbed quartzite on Beinn a' Mhuinidh has been carried westwards to a point beyond Rhu Noa Pier on Loch Maree; and that (3) the outcrop of the Moine thrust-plane has been also borne westward from the hill-slope east of Bruachaig to the valley at the Kinlochewe Hotel. In like manner the axes of the compound syncline and anticline between Beinn a' Mhuinidh and Abhuinn Bruachaig have been moved further west on the south side of the displacement to Meall Ghiubhais and the ridge south-west of Tagan. Accompanying this horizontal displacement there has been a vertical downthrow of about 1000 feet on the north side of the Loch Maree fault.

Southwards, in the direction of Beinn Eighe and the Coulin deer forest, further evidence has been obtained of the enormous compression of the Torridonian and Cambrian strata by reversed folds and faults in advance of the Kinlochewe thrust, and of the deformation of the Torridon Sandstone beneath or close to the Moine displacement. The Kinlochewe or Ben More thrust-plane can be followed southwards from the Cromasag Burn to Loch Clair, where the Torridon Sandstone overrides successive zones of the quartzites and fucoid-beds. Thence the outcrop of the thrust-plane passes southwards through the Coulin Forest, skirting the western base of Cnoc Daimh, and by the east declivity of Carn Odhar to Achnashellach. Over the greater part of this ground it is difficult to locate the exact position of the Moine displacement, owing to the development of mylonised rocks and to the metamorphism of the basal parts of the Torridon Sandstone overlying the Kinlochewe thrust-plane, where they assume a structure resembling that of Moine-schist.

The structure of the mountainous ground rising to the west of Kinlochewe is represented in the section drawn in Fig. 50. At the west end of this section the Fasagh fault, with a downthrow to the east, is shown in the Torridon Sandstone. The line of section then runs eastwards along the crests of the long ridge of Beinn Eighe. The summit of Sail Mhor, the most westerly peak of the mountain, is capped with a small outlier of basal quartzite (Ca). Further east the successive members of the arenaceous series, resting unconformably on the Torridon Sandstone, are followed in order by the fucoid-beds (Cc) and part of the serpulite-grit (Cd). For a considerable distance the various zones of the pipe-rock (Cb) are repeated by isoclinal folds, sometimes accompanied by minor thrusts. About a mile and a half east of Sail Mhor the Torridon Sandstone (Bb) is superimposed on the basal zone of the pipe-rock by means of a minor thrust. The red sandstones form here a continuous belt across the mountain, and further east they are again covered unconformably by the quartzite (Ca), followed by the pipe-rock (Cb) up to the fourth sub-zone, which is in turn truncated by another reversed fault that brings forward the basal quartzite. On Sgurr Ban a conspicuous anticline and syncline of the Torridon Sandstone and Cambrian quartzite are visible on

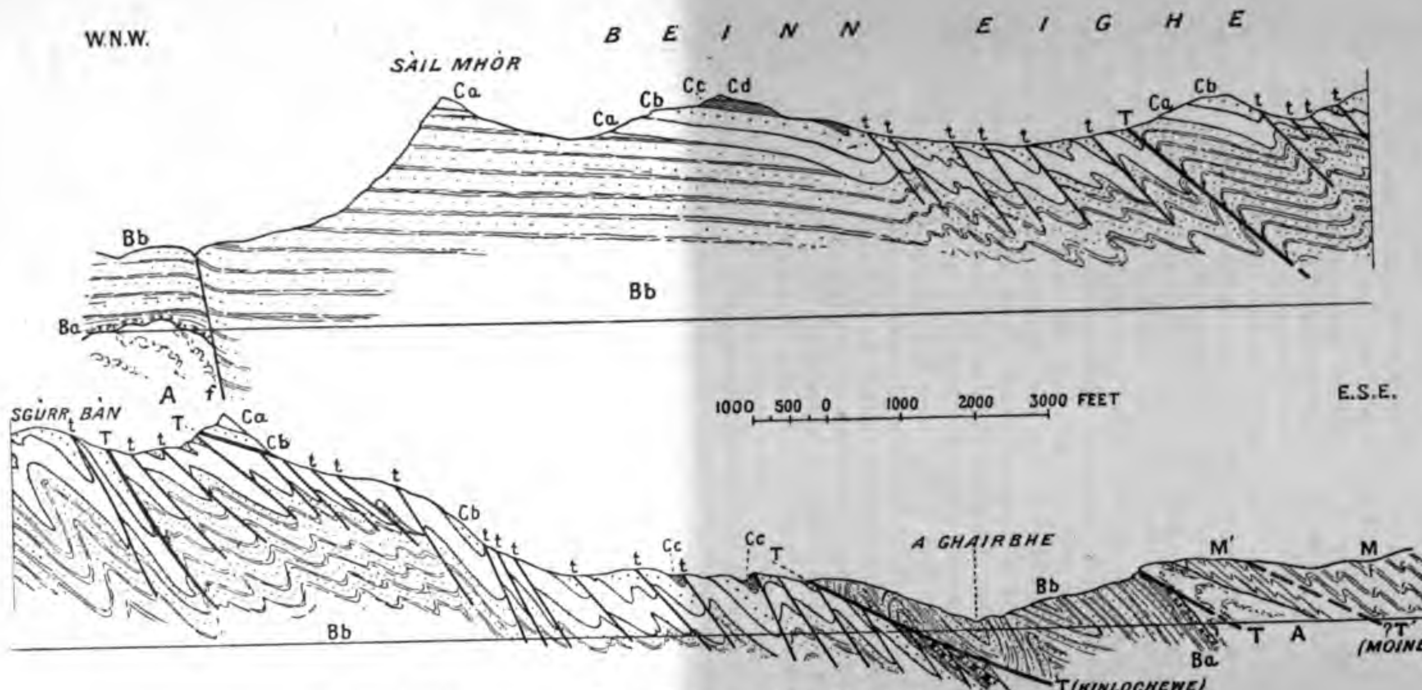

FIG. 50.—Section across Beinn Eighe to A Ghairbhe, south of Kinlochewe.

A. Lewisian Gneiss. Ba. Diabaig Group (Torridonian). Bb. Applecross group. Ca. Basal Quartzite (Cambrian). Cb. Pipe-rock. Cc. Fucoid-beds. Cd. Serpulite-grit. M'. Mylonised Rocks, Phyllites, and Siliceous Schists. M. Moine-schist. T. Thrusts. ?T'. Moine thrust. t. Minor thrusts. f. Fault.

the north and south slopes, where the isoclinal nature of the folding is clearly displayed.

Beyond Sgurr Ban, along the ridge towards Meallan na Circe-fraoich for a distance of two miles, the various zones of the arenaceous series are constantly reduplicated by inverted folds and reversed faults. An examination of the southern slope in an easterly direction about the 1250-feet contour-line shows that the underlying Torridon Sandstone has participated in these flexures and displacements. Notwithstanding this extreme plication, however, the rocks have not been much deformed. Here and there the Torridon Sandstone has been crushed and is traversed by quartz-veins. On the further side of the Kinloch-ewe thrust-plane (T), which is well seen in small burns about a mile north from Loch Clair, close by the junction of the roads leading to Torridon and Coulin Lodge, the metamorphism of the Torridon Sandstone is well developed. Above this line of disruption the beds of arkose of the Applecross group (Bb), dipping to the E.S.E., are exposed in the stream (A' Ghairbhe) that issues from Loch Clair. West of the river the bedding planes in these strata are preserved, but in the stream-section at Doire na Gairbhe and below that point they have been effaced, the beds becoming schistose along planes parallel with those of thrust. The larger grains of quartz and felspar in these rocks have been elongated and appear as eyes in a mylonitic matrix, in which minute flakes of sericitic mica have been developed, showing that in addition to the differential movement of the constituents a certain amount of reconstruction has been induced.

On the east side of the A' Ghairbhe River the sheared grits are succeeded in inverted order by black and grey shales, flags, and epidotic grits of the basal division of the Torridon Sandstone (Diabaig group, Ba), until these strata plunge under a crag of Lewisian gneiss (Creag Ghairbhe) traceable southwards to Loch Coulin. The Torridonian sediments are here all more or less schistose, and in places show a marked platy structure similar to that of the mylonised rocks associated with the Moine-schists. Sericitic mica has been developed on their divisional planes, and frequently lines of striping appear on the surfaces of the horn-stone like bands, trending in the direction of the post-Cambrian movements. Generally the deformation and reconstruction increase towards the junction with the overturned gneiss. These metamorphic structures are well displayed along the face of the crag that runs southwards from Doire na Gairbhe to the south-east corner of Loch Clair. The inverted base of the Torridon Sandstone appears along this crag, though in the line of section it is cut out by a thrust, but of no great moment.

The wedge of overlying gneiss has likewise been deformed, though the original structures of the rock are still traceable. Beyond this appearance of the ancient Lewisian floor mylonites (M′) supervene, showing the double system of folding characteristic of the Moine-schists, and soon followed by the siliceous flagstones of the Eastern series (M). Not improbably the

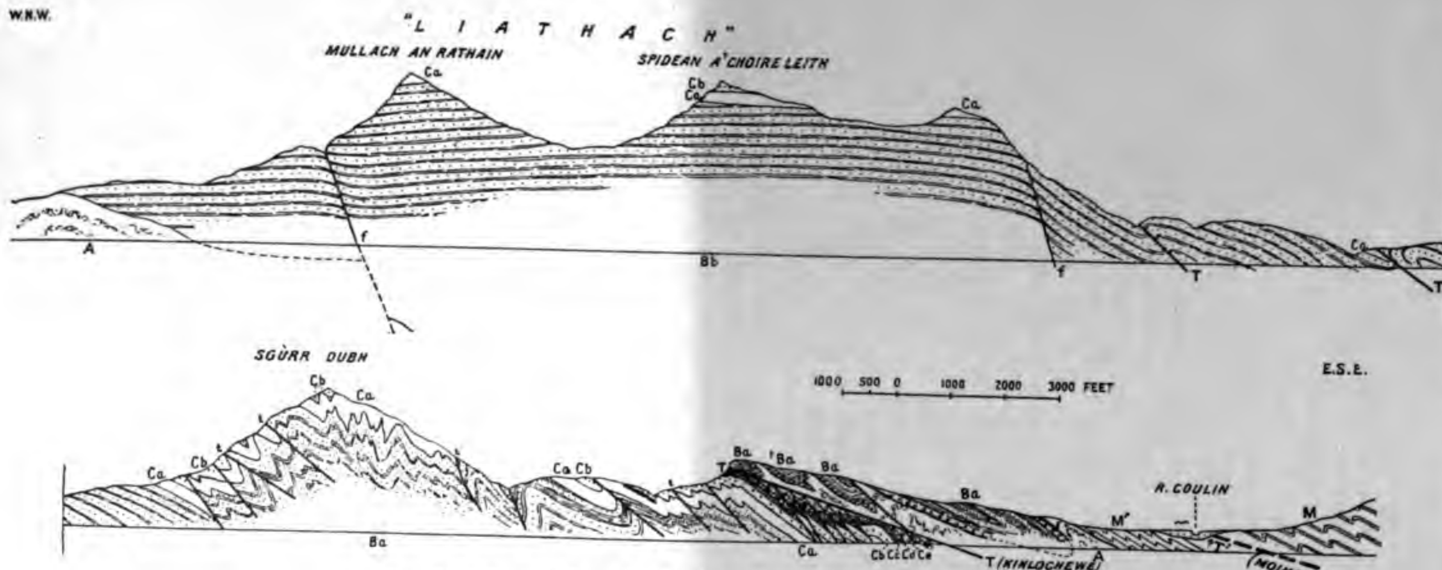

Fig. 51.—Section from Liathach by Sgùrr Dubh to the River Coulin.

A. Lewisian Gneiss. Ba. Diabaig group (Torridonian). Bb. Applecross group. Ca. Basal Quartzite (Cambrian). Cb. Pipe-rock. Cc. Fucoid-beds. Cd. Serpulite-grit. Ce. Limestone. M'. Mylonised Rocks, Phyllites, and Siliceous Schists. M. Moine-schist. T. Thrusts. ? T'. Moine thrust. t. Minor thrusts. ∼ Alluvium.

Folded Torridonian and Cambrian strata, with thrust Torridon Sandstone on right (dark) above bare thrust-plane of Quartzite (light). South face, Beinn Liath Mhor, Ross-shire.

epidotic grits and dark flags of the Torridonian series may be represented in this mylonised zone between the Lewisian gneiss and siliceous flagstones.

The section given in Fig. 51 is drawn through the high ridge of Liathach (3456 feet) eastwards across the head of Glen Torridon and Sgurr Dubh to the Coulin River. Its eastern portion is of special importance on account of the supplementary evidence which the ground traversed by it affords of the deformation of the Torridon Sandstone above the Kinlochewe (Ben More and Kishorn) thrust-plane, and of the presence of certain sediments of intermediate type between the deformed members of the Torridonian Diabaig group and the granulitic schists of the Moine series.

At the west end of this section a hill of Lewisian gneiss is seen to protrude through the red sandstones to a height of 800 feet. On the west slope of Mullach an Rathain the position of the Fasagh fault is represented. The enormous pile of red sandstones on Liathach is capped with outliers of Cambrian quartzite, including the false-bedded grits (Ca) and part of the pipe-rock (Cb). On this mountain the Torridon Sandstone and overlying Cambrian rocks have been thrown into a flat arch, on the west side of which the red sandstones present the westerly dip characteristic of them in Applecross to the south, and likewise in the northern district of Stoer in Assynt and the Parph west of Durness.

High up on the eastern slope of the most easterly peak of Liathach a normal fault (f) lets down the sandstones on that side, beyond which for two miles the ground is occupied by beds of arkose (Applecross group) interrupted by two minor thrusts.

On Sgurr Dubh (2566 feet)—a prominent feature in the landscape as seen from Kinlochewe—the Torridon Sandstone and basal quartzite display incipient fan-structure, the beds being inverted and repeated by minor thrusts on the western declivity. On the crest of the mountain infolds of the lowest sub-zone of the pipe-rock (Cb) have survived. The eastern slope displays several compound flexures of the red sandstones and overlying quartzite. South-eastwards beyond the slope drained by the two tributaries of Allt na Luib, where the usual repetition may be seen of both divisions of the arenaceous series (Ca, Cb), the western flank of the hill that overlooks Loch Coulin presents the outcrop of the Kinlochewe thrust-plane, with the basal members of the Torridon Sandstone (Ba) above it and the fucoid-beds (Cc) below.

It may be mentioned that on the south slope of Cnoc Daimh, where the driving together of the fucoid-beds, serpulite-grit, and basal limestone is admirably displayed beneath the Kinlochewe thrust-plane, the general structure differs to some extent from what appears in Assynt and thence northwards to Eireboll. The piled-up strata have not here been driven westwards along an underlying plane of movement or "sole," for the minor folds and thrusts are traceable downwards into the underlying pipe-rock.

The strata which have here been carried forward on the Kinlochewe thrust-plane belong to the Diabaig group (Ba) of the Torridon Sandstone, and comprise epidotic grits, black and grey shales and flags, and thin bedded sandstones with cores of Lewisian gneiss, arranged in isoclinal folds that dip to the E.S.E. at angles varying from 15° to 36°. Several of these gneiss lenticles which occur on the hill one mile N.N.W. of Cnoc Daimh cannot be traced far, but the most easterly one forms a continuous band extending southwards from Loch Coulin and across Cnoc Daimh to Easan Dorcha.

An examination of the hill west of the keeper's house at Coulin and in Allt Cnoc Daimh has shown an increase in the grade of metamorphism as the rocks are followed eastwards from the Kinlochewe thrust-plane. On the hill-top the most westerly arch of Lewisian gneiss (A, Fig. 51), 150 yards east of the thrust-plane, forms a lenticle about 200 yards long, flanked by the epidotic grits and black shales (Ba), which dip east at angles from 13° to 35°. Beyond an interval of 300 yards, in which an inverted syncline of the Diabaig group appears, the second inverted anticline about 100 yards long of Lewisian rocks consists of green epidotic gneiss with eyes of hornblende-rock. Here the Torridonian strata have not been much deformed, though they become rudely schistose in places. But 300 yards further east at the third arch of gneiss the metamorphism is much more pronounced. On the west limb the basal epidotic grits are concealed by a small thrust, but they rise from underneath the gneiss lenticle on the north and rest unconformably on it on the east. A small burn that crosses the eastern limb of this fold has exposed the epidotic grits in an intensely-sheared condition, with abundant sericitic mica and secondary magnetite. These altered rocks are regarded by Dr. Teall as similar to the Torridonian rock at Fernaig, which under the microscope presents structures like those of Moine-schists. Five hundred yards further east a fourth fold of Lewisian gneiss, the most easterly of the series, appears, underlain by similar sheared epidotic grits. Although only this fold is exposed a little to the south in the Cnoc Daimh Burn, the evidence furnished by this stream is of extreme interest. Below the 800-feet level an almost continuous section has been laid bare of the grey and black slaty shales, flags, and epidotic grits, dipping eastwards in inverted order at angles varying from 10° to 12°. The grits are sheared and their quartz grains more or less granulitised. Not far below the 500-feet level the Lewisian gneiss overlies the inverted basal conglomerate of the Diabaig group, the gritty matrix of which is intensely sheared and contains epidote, chlorite, and magnetite, like the rock at Fernaig above referred to.

The acid gneiss with basic lenticles which overlies this basal conglomerate has been so intensely crushed that it has been described by Dr. Teall as having the appearance of a clastic rock with much secondary mylonitic material. It is visible in the stream at the bend below the 500-feet contour-line. Below it for a distance of 250 yards the stream exposes a continuous section of strata of sedimentary origin, resting on the deformed Lewisian gneiss, and presenting slightly different characters from the Diabaig beds in the inverted limb of the arch. At its upper margin the epidotic gneiss is practically a mylonite. It is immediately succeeded by fine-grained, dark platy schist, which Dr. Teall finds to be composed of quartz, felspar, sericitic mica, small scales of brown mica, and minute grains of epidote. He further notes " that under a low power this rock resembles a sandy shale, but under a high power the structure is more allied to that of a crystalline schist. It is difficult to avoid the conclusion that this is one of the sandy shales of the Torridon system." It may be remarked that this platy rock has the alternating dark and grey films so characteristic of the shaly bands of the Diabaig group, but the basal conglomerate, so well developed on the inverted limb of the arch, is here unrepresented.

About the 400-feet level these dark platy schists contain a few garnets, and, further down stream, they are succeeded by fine-grained grey siliceous schist with scattered "eyes" of felspar. Dr. Teall remarks of this rock that it "appears to be a sheared epidotic grit, and, like the previous finer-grained rocks, is intermediate in structure between a normal sediment and a true crystalline schist." The precise geological horizon of these intermediate strata (M′) is uncertain. If they represent the basal beds of the Diabaig group, it is obvious that they mark a higher grade of metamorphism than the same bands on the inverted limb of the arch. Beyond the alluvium of the River Coulin the normal granulitic schists of the Moine series make their appearance, the outcrop of the Moine displacement being not improbably concealed under the alluvium.

At no part of the long belt of complicated structure is the evidence of great displacement more clearly visible, even from a distance, than in the range of wild mountainous ground lying between Glen Torridon and Strath Carron. In the Beinn Liath group of hills the dark Torridon sandstones and the white Cambrian quartzites present such a contrast of colour as to reveal on the steep declivities the positions into which the two groups of rock have been thrown by plications and ruptures. The structure of this ground is illustrated by the section in Fig. 52 and in Plate XXXIX. At the west end of the great ridge of Beinn Liath Mhor the basal quartzite (Ca) and pipe-rock (Cb) have been thrown into a series of compound flexures, all inverted and truncated on the east side by a reversed fault. On the slopes of the westmost and highest peak of the mountain (3034 feet) the great folds of Torridonian and Cambrian strata are clearly displayed, arranged in a compound anticline and syncline. The westerly arch of Torridon Sandstone is shown on the left side of Plate XXXIX., and appears on the mountain top in basal quartzite (Ca) that passes below pipe-rock (Cb) to the east and west (Fig. 52). Beyond the second infold of pipe-rock,

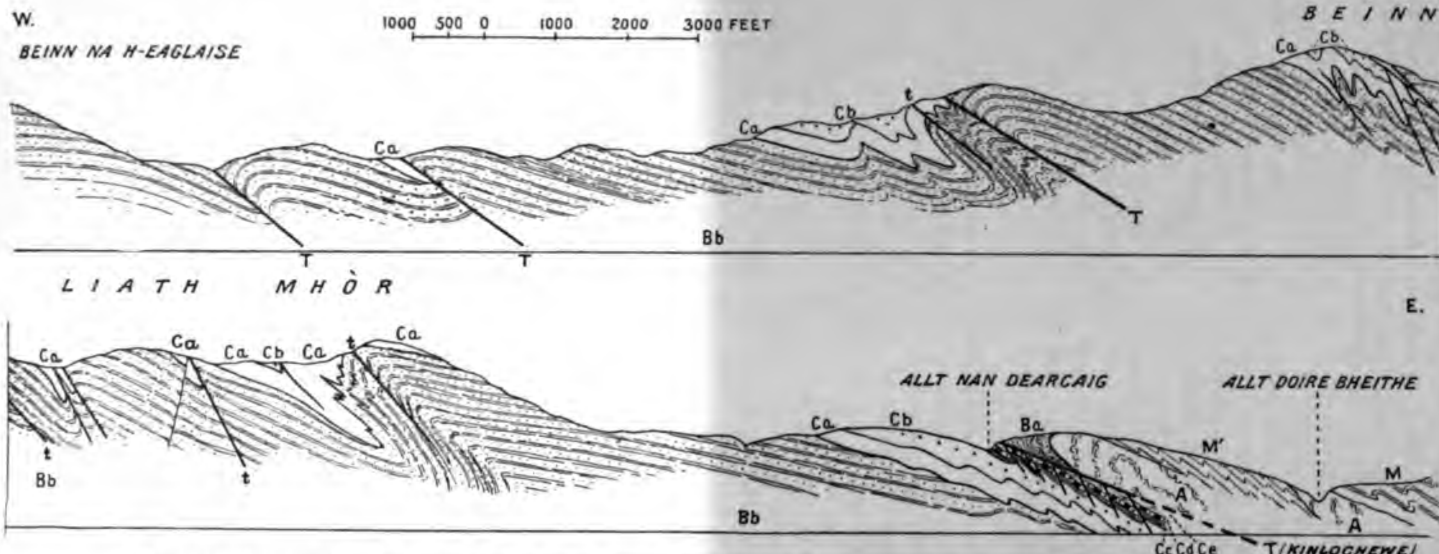

FIG. 52.—Section from Beinn na h-Eaglaise along Beinn Liath Mhòr to Allt Doire Bheithe, Auchnashellach Forest.

A. Lewisian Gneiss. Ba. Diabaig group (Torridonian). Bb. Applecross Group. Ca. Basal Quartzite (Cambrian). Cb. Pipe-rock. Cc. Fucoid-beds. Cd. Serpulite-grit. Ce. Limestone. M'. Mylonised Rocks, Phyllites, and Siliceous Schists. M. Moine schist. T. Thrusts. t. Minor thrusts.

which is overridden by a patch of basal quartzite, the bare thrust-plane may be seen along which the Torridon Sandstone has been driven.

Further east on the ridge small patches of basal quartzite again appear, truncated in succession by reversed faults, till near the eastmost peak a great fold of the arenaceous series (Ca, Cb) runs down the southern slope for 1000 feet. Northwards this infold of quartzite can be traced across Allt Coire Beinne Leithe to Beinn Liath Beag. On the eastern limb of the syncline on the top of the ridge the basal quartzite dips to the west at angles varying from 25° to 72°, but on the southern slope the beds are inverted and the junction line is corrugated. Here also the inverted arch of Torridon Sandstone culminates in a minor thrust, which, though of small amount, forms a conspicuous feature on the northern declivity, and is traceable to the N.N.E. for two miles. The Torridon Sandstone capped by the basal quartzite dips gently to the east on the eastmost peak. The section here described illustrates two important features in the tectonics of the region—(1) that a normal fold may pass gradually into an inverted fold, the dip of the axial plane being to the E.S.E., the direction from which the pressure came; and (2) that an overfold may pass upwards and laterally into a reversed fault or thrust.

East from Beinn Liath Mhor the outcrop of the Kinlochewe thrust-plane runs on the east side of the valley of Allt nan Dearcaig, where a slice of Lewisian gneiss (A) and the inverted beds of the Diabaig group (Ba) have been driven westwards over the piled-up Cambrian strata. Beyond the gneiss mylonised materials (M′) and the Moine-schists (M) come in, together with an inlier of gneiss of Lewisian type exposed in Allt Doire Bheithe.

CHAPTER XXXVIII.

STRUCTURE OF THE GROUND BETWEEN AUCHNASHELLACH AND LOCH ALSH.

I. AREA BETWEEN AUCHNASHELLACH AND KISHORN.*

The area of disturbance in the Coulin and Auchnashellach Forests, described in the previous chapter, is bounded on the west by a line of thrust, which, crossing the crest of Beinn Eighe, about one mile west of Sgurr Ban, runs southward over the eastern shoulder of Liathach and the hills south of Glen Torridon to Loch nan Eun. It is thence continued southwards to the west of An Gorm Loch, where it is overlapped by another thrust, which brings forward heaped-up pipe-rock.

The area to the east of this line of dislocation is occupied by successive narrow belts of Cambrian and Torridonian strata, carried westward on a series of parallel major thrust-planes which run N.N.E. and S.S.W. The effect of the first of these, the course of which has just been traced, is to thrust the Torridonian rocks upon themselves along the greater part of the line of disruption. The Cambrian quartzites, however, appear beneath the thrust on the southern face of Beinn Eighe, and on the hill-top immediately south of Glen Torridon a small patch of the basal quartzite, resting in normal sequence on the Torridonian, is laid bare for a short distance below the thrust-plane. In Strath a' Bhathaich, at a point half a mile east of Loch na Suileig, a wedge of Cambrian strata makes its appearance beneath the thrust-plane, and the Torridonian grits which overlie that plane pass transgressively from the unmoved Torridonian on to the successive zones of the quartzite. Near An Gorm Loch, about a mile and a half south-west of An Ruadh-stac, the thrust passes entirely into the Cambrian strata, bringing forward the pipe-rock upon itself along the slopes above Allt Ghiubhais as far as the Coille Dhubh (Sheet 81). From this point westwards to the Kishorn the Middle Cambrian series is thrown against the undisturbed serpulite-grit along the outcrop

* This section of the present chapter is supplied by L. W. Hinxman. This district is contained in Sheets 71, 81, and 82 of the Geological Survey Map of Scotland, on the scale of one inch to a mile.

of the thrust; though above Loch an Loin the latter is for some distance overlapped by a "sole," upon which the heaped-up limestones of Glen Kishorn have been brought forward.

The next thrust to the east crosses the head of Glen Torridon at Lochan Iasgaich, and runs with a somewhat sinuous course to Loch an Eoin, north of Meall a' Chinn Deirg, for the most part thrusting the Torridonian series upon itself. But small lenticular patches of basal quartzites appear, as in the first thrust, beneath the thrust-plane near Lochan Iasgaich, and in the crag above Loch Meall a' Ghuaill, two miles south of Glen Torridon. A conspicuous feature marks the course of the thrust above the western shores of Loch an Eoin, whence the outcrop sweeps round the scarped front of Meall a' Chinn Deirg (3060 feet). This dislocation has brought forward the Torridonian grits (Bb) and the striped sandstones of Group III. that form the top of the last-named mountain, and has placed these strata upon the folded Cambrian quartzites (Ca, Cb) on its steep western face (Fig. 53) and the hill-slopes that stretch southwards between Loch Coire an Ruadh Stac and Loch Cadh' an Eididh, about a mile and a half S.S.W. of An Ruadh-stac. The quartzite rises in a steep cliff above the southern shore of the latter loch, curves round to meet the thrust, and completely overlaps the sandstones; while the thrust-plane, a short distance further south, buries itself beneath the piled-up fucoid-beds and serpulite-grit at the head of Allt a' Ghiubhais.

A third mass of Torridonian and Cambrian strata has been driven westward and superimposed transgressively upon the different zones and sub-zones of the Cambrian quartzite by a thrust which leaves the road at Loch Maireannach, near the head of Glen Torridon, and traverses the steep western face of Sgurr Dubh and the hills to the south a short distance west of the watershed. Between Sgurr Dubh and Lochan Uaine, at the base of the north slope of Beinn Liath Mhor, the dip of the thrust-plane is generally low, but as this plane passes through Coire Granda and crosses the western peak of Sgurr Ruadh—where the sandstones rest upon intensely-folded basal quartzite—the angle of inclination rises from 30° to nearly 60°. The amount of disruption lessens as the outcrop is followed down into the head of Coire Fionnaridh, and on the slopes of Meall a' Chinn Deirg on the further side of the glen the thrust appears to have passed into an inverted fold.

The structure of the district will be most conveniently explained by means of some sections drawn across it. One of these (Fig. 53), which runs from Beinn Damh (2958 feet) in a south-easterly direction to Strath Carron, shows at its west end the Cambrian quartzites (Ca) resting unconformably and at a lower angle and inclination upon the Torridon Sandstone (Bb), the basal quartzite lying almost flat at the west end of the outlier which caps Beinn Damh. On the steep eastern face of the mountain the sandstones dip west at a high angle beneath the quartzite, but further down the slope the inclination rapidly

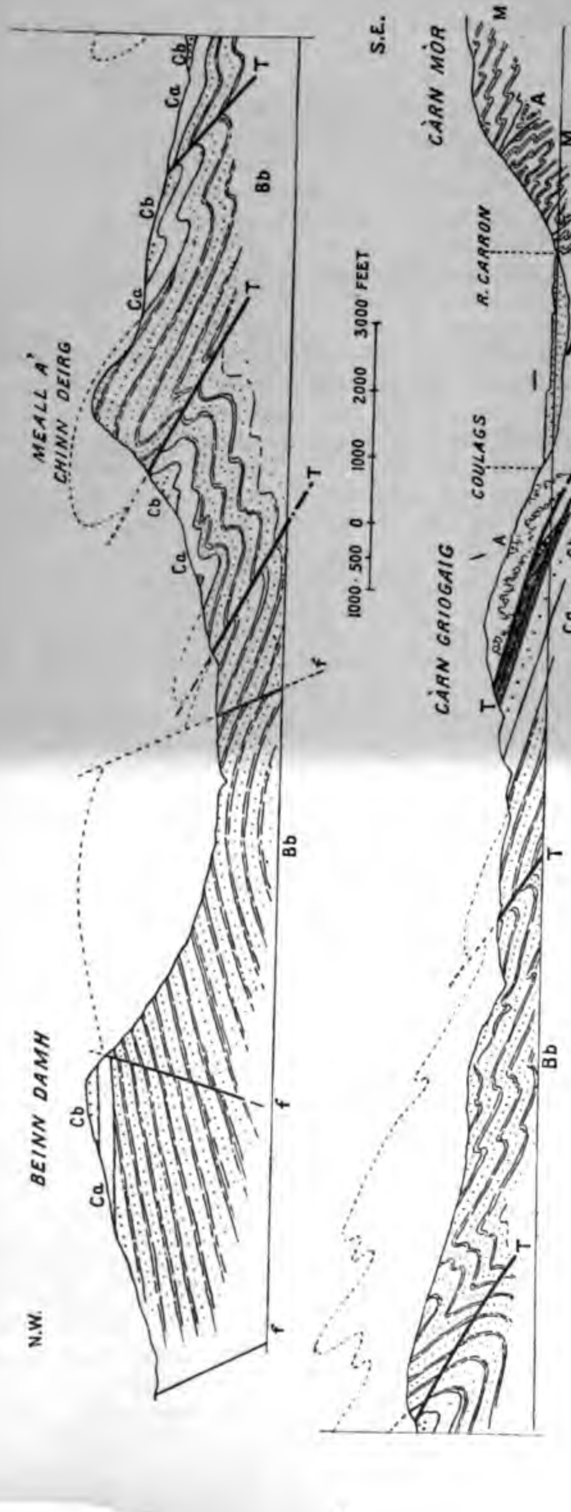

FIG. 53.—Section from Beinn Damh across Meall a' Chinn Deirg to Coulags in Strath Carron.

A. Lewisian Gneiss. Bb. Applecross group (Torridonian). Ca. Basal Quartzite (Cambrian). Cb. Pipe-rock. Cc. Fucoid-beds.
M. Eastern Schists. T. Thrusts. ?T'. Moine thrust. f. Faults. ~ Alluvium.

lessens towards a great anticlinal fold in the line of Strath a' Bhathaich, till on the eastern side of that valley the beds dip to the south-east.

A short distance up the south-eastern slope of the same valley the boundary of the disturbed area is marked by the outcrop of the first major thrust, by which a wedge of Torridonian and Cambrian strata has been brought in along the lower part of the steep face of Meall a' Chinn Deirg. The two zones of the quartzite (Ca, Cb) are introduced by a sharp inverted fold, which includes a number of minor plications. The eastern limb of this fold is truncated by the next major thrust, which has carried westward more than 1000 feet of Torridonian rocks. The upper portion of this mass, which forms the summit of the mountain, is composed of fine-grained, violently false-bedded red sandstones. The laminæ indicating current-bedding are usually here as elsewhere inclined at a high angle to the true bedding-planes, and often much contorted. Intercalated with the sandstones are several bands of greenish-grey flags and shales, one of which, at the base of the series, reaches an average thickness of 15 feet, and can be traced for nearly a mile. Similar rocks are found on the summit of Fuar Tholl, three and a half miles to the east, and, with those described above, may be assigned to the Cailleach Head group (III.) of the Torridonian series.

On the eastern slope of Meall a' Chinn Deirg the red sandstones are again followed unconformably by the Cambrian pipe-rock and basal quartzite, which are repeated by normal and inverted folds cut off on the east by a minor thrust. A few yards to the east of the second of these, the Torridon grits and striped sandstones once more make their appearance and rest in an inverted position upon the basal quartzite, both dipping south-east at angles of 25°-30°. The folded inverted junction is well displayed in the cliffs two-thirds of a mile north of the loch at the head of Allt nan Ceapairean, which drains the eastern slope of An Ruadh-stac.

For two miles eastward from this point the ground is occupied by isoclinally-folded Torridonian strata belonging for the most part to the arkose group (Bb) and dipping uniformly S.E.-S.S.E. at an average angle of 15°. On the west side of Coire Fionnaridh the basal quartzite and pipe-rock again appear in natural sequence, followed in places by the fucoid-beds, which crop out at intervals from beneath a cake of thrust material, which, brought forward on two thrust-planes, covers the eastern slope of Carn Griogaig and descends to the roadside between Coulags and Balnacra in Strath Carron.

The rocks which rest upon the plane of the first of these thrusts consist of the middle members of the Cambrian series, repeated and driven together by numerous reversed faults. These strata are in turn overridden by the Kishorn thrust, which has here pushed westwards a mass of mylonised flaggy Lewisian gneiss (A). The rocks which repose upon the sole of this maximum thrust overlap in places the piled-up strata below, as well as the fucoid-beds on which these strata lie. On the top of the hill the gneiss can be seen resting directly upon the pipe-rock. An isolated portion of this thrust mass of material is found on the hill-side immediately above the foot of Loch Dhugaill in Strath Carron. It is bounded on the south side by a normal fault which forms a deep gully up the declivity. The precipitous southern face of this ravine is composed of shattered pipe-rock, while on its northern side the Kishorn thrust-plane is well exposed in section. The crushed and mylonised gneiss may there be seen to rest upon sheared fucoid-shales and dolomite. The rocks along this line of dislocation are much reddened, and filled with veins of calcite and hæmatite.

East of the Carron valley the granulitic quartzose schists of the Moine series (M), with inliers of Lewisian gneiss (A), are represented, and their relations to the displaced masses are not visible. The position of the Moine thrust, if present, is beneath the alluvial deposits of the River Carron, as shown in Fig. 53.

In the ground to the south of that represented in the foregoing section the structure of the disturbed belt becomes more complicated. The Torridon Sandstones that overlie the first thrust-plane on the east side of Strath a' Bhathaich are succeeded unconformably by the Cambrian quartzites, which have been thrown into a double isoclinal fold on the lower slopes of Ruadh Stac, whereby the outcrops of the pipe-rock and basal quartzite are repeated. Further up the side of that hill the eastern limb of this double fold is truncated by the second major thrust, which again brings forward a mass of Torridonian and Cambrian strata. The quartzites that form the crest and steep eastern face of the mountain are arranged in a series of complex isoclinal folds, most of which are broken on the eastern side by minor thrusts, the amount of displacement in each case being, however, comparatively small. The intensity of the folding is well illustrated on the bare glaciated ridge between Ruadh Stac and Loch Cadh' an Eididh, where the different sub-zones of the pipe-rock are so distinctly traceable that the structure of the ground can be followed with comparative ease. From the foot of Ruadh Stac south-eastwards to Strath Carron the tectonic arrangement of the rocks is similar to that shown in the eastern part of the section drawn in Fig. 53.

The greater complexity of the structure in a southerly direction may be further illustrated by another section (Fig. 54) drawn, not far from the ground traversed by the last, in a south-easterly direction from the valley of Strath a' Bhathaich across the ridge of Glas Bheinn to the head of Loch Carron at Kirkton. At the north-western end of this section the same anticlinal fold and the Fasagh fault are shown as in Fig. 53 traversing the Torridon Sandstones (Bb), which are succeeded unconformably by the lowest members of the Cambrian series (Ca-Ce).

South of the Gorm Loch, above the major thrust-planes, a considerable area round the upper part of the Allt a' Ghiubhais glen

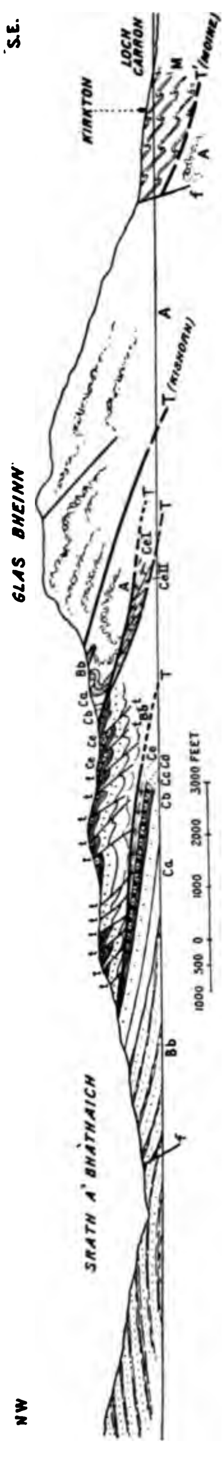

FIG. 54.—Section from Srath a' Bhathaich by Glas Bheinn to Kirkton on Loch Carron.

A. Lewisian Gneiss. Bb. Applecross group (Torridonian). Ca. Basal Quartzite (Cambrian). Cb. Pipe-rock. Cc. Fucoid-beds. Cd. Serpulite-grit. Ce. Limestone. Ce I. Limestone (Ghrudaidh group). Ce II. Limestone (Eilean Dubh group). M. Eastern Schists. T. Thrusts. T'. Moine thrust. t. Minor thrusts. f. Faults.

and the pass that leads through to Strath Carron is occupied by repetitions of the fucoid-beds, serpulite-grit, and basal limestone, folded and driven together in great complexity. On the south side of that glen this mass of piled-up material is soon overlain by limestones belonging to the Ghrudaidh and Eilean Dubh groups. These have been carried forward by a thrust which traverses the southern slopes of the Kishorn valley, and gradually descends to the roadside at Rassal, where it is cut off by the Fasagh fault. A belt of ground, five miles in length and nearly three-quarters of a mile in breadth, is occupied by these limestones, which, though inclined at very high angles, are made to spread over so large an area by being incessantly repeated by folds and reversed faults.

A short distance west of the Allt a' Ghiubhais pass the limestones are themselves overlapped by another thrust-plane on which the quartzite has been carried westward. On the watershed at the head of the pass the pipe-rock dips at a high angle beneath the basal quartzite, which is in turn followed in inverse order by Torridonian grits, these again being overlain in a similar manner by Lewisian gneiss. The double unconformability is thus represented here in inverted order. Owing, however, to folding and crushing, the boundary lines of the different rocks are considerably involved, and it is besides often extremely difficult to separate the basement breccia of the Torridonian series, made up as it is of fragments of gneiss, from the gneiss itself.

On the south side of the pass rise the steep craggy sides of Glas Bheinn, a mass of Lewisian gneiss which has been brought forward by a powerful dislocation (Kishorn thrust) that truncates the different members of the Cambrian and Torridonian series between Loch Dhugaill in Strath Carron and Loch Kishorn. This great line of disruption runs northward from Loch Kishorn to Tornapress, whence it follows the course of the Allt Mor and sweeps round the base of Glas Bheinn to the head of the Tullich Glen. The materials driven forward upon its sole consist of Lewisian gneiss (A) and portions of the lowest Torridonian group (Ba). The two formations preserve their normal unconformable relations, but in inverted order, so that the gneiss rests upon the younger rock and forms the highest part of the hill.

The Kishorn thrust-plane is well displayed in the deep ravine cut by the Allt Mor above Tornapress. Its angle of inclination is here high, ranging from 50° to 80°. The stream flows along the actual line of dislocation, between steep walls composed on the one side of crushed and reddened Eilean Dubh limestone, and on the other of sheared Torridon grits and flagstones.

The same plane of movement is laid bare along the stream that flows eastward from the head of the Tullich Pass into the Amhainn Bhuidheach, where also the water follows the line of displacement between the quartzite below and the mylonised gneiss above.

East of the Tullich Glen the moved mass of Lewisian rocks which lies upon the Kishorn thrust-plane is for the most part underlain by the platform of fucoid-beds and serpulite-grit that have been driven together as above described. In places, however, the gneiss overlaps on to the fucoid-beds and pipe-rock below the sole on which these Cambrian strata have been carried forward. The thrust-plane finally descends to the valley of Strath Carron near Coulags, where it is concealed beneath the alluvium of the River Carron.

In addition to the great lines of disruption here described, the successive masses of Torridonian and Cambrian strata brought forward on the major thrust-planes have undergone a further amount of intricate plication and movement, which, though perhaps as much developed in the older as in the younger formation, can only be recognised in its full complexity among the easily-distinguishable zones and sub-zones of the Cambrian series.

Only a comparatively feeble degree of metamorphism is observable among the successive masses of Torridonian grit and sandstone where they have been cut through by the thrust-planes, except in the case of the Kishorn thrust. A certain amount of crushing and incipient shearing can be detected along the line of the major thrusts in Glen Torridon and on the slopes of Meall a' Chinn Deirg, though at a short distance from the line of disruption the rocks often appear to be entirely unmodified. The appearance of veins and strings of white quartz in the otherwise unaltered sandstones is an invariable feature in the thrust masses. Though no interstitial movement has taken place in these rocks, they have been much fractured and jointed, the resulting cracks and fissures being now filled with segregated quartz forming a network of ramifying veins, which on glaciated and weathered surfaces stand out in high relief.

It is along the line of the great Kishorn or Kinlochewe thrust-plane that the internal differential movement in the rocks has reached in this district its maximum development. The Torridonian grits and sandstones have been converted into green and red flagstones, in which the constituent particles have been drawn out along the lines of movement, and the original lithological character of the rocks has been more or less obliterated. The basal shaly beds pass into black slaty schists and flagstones; and the immediately overlying gneiss, partaking in the same movements, is crushed and mylonised to such a degree that in some places it is difficult to determine the actual junction-line between the two formations. Even the basal Torridonian breccia is in some places simulated by a pseudo-conglomeratic rock, which has been produced by the crushing of the gneiss where it is filled with veins of pegmatite.

On the east side of Glas Bheinn (Fig. 54) the relations of the Moine-schists to the Lewisian gneiss are unfortunately obscured by a normal fault, which throws down the siliceous flagstones and phyllites of the Moine series (M) against the deformed gneiss. But immediately to the west of this dislocation it is evident that the original characters have here been effaced, the rocks having been converted into the banded mylonites with marked flaser structure, which have been shown in the previous chapters to be so persistent an accompaniment of the Moine thrust-plane.

II. AREA BETWEEN LOCH KISHORN AND LOCH ALSH.*

The most striking feature of the belt of complication in the ground now to be described is the stupendous inversion of the Torridon Sandstone and Lewisian rocks above the Kishorn thrust-plane. The overturned gneissic floor, lying at a gentle angle on the inverted epidotic grits, black shales, and sandstones of the lowest Torridon division, forms a bold and conspicuous escarpment to the north and south of the entrance to Loch Carron. The boundary line between the two formations has been traced from the western slope of Cearcall Dubh, north-east of Kishorn, southwards to a point in Loch Carron about a mile west of North Strome, thence on the south side of the loch by Fernaig and the prominent crag east of Duncraig to Gleannan Dorch, where it is truncated by the Balmacara thrust. This remarkable piece of topography, so continuous for several miles, is without parallel in the North-West Highlands.

Within the belt of complication in this district a high grade of metamorphism is observable among the lowest Torridon strata usually at or near their inverted base-line. This alteration may be studied with advantage at Fernaig in the conglomerate which

* This section is by B. N. Peach and J. Horne.

Fig. 55.—Section from Loch Kishorn by An Sgòrr to Slumbay, Loch Carron.

A. Lewisian Gneiss. B^G Epidiorite and Hornblende-schist in Gneiss. Ba, Ba^1 to Ba^2. Diabaig group (Torridonian). Bb. Applecross group. Ca. Basal Quartzite (Cambrian). Cb. Pipe-rock. Cc. Fucoid-beds. Cd. Serpulite-grit. Ce I. Limestone (Ghrudaidh group). Ce II. Limestone (Eilean Dubh group). M. Eastern Schists. T. Thrusts. T'. Moine thrust. f. Faults.

crops out there. This rock is traceable only for a limited distance, but when it is absent its place is taken by epidotic grits and shales, which lie in contact with the old floor of gneiss. Considerable differential movement has taken place in some parts of the Lewisian rocks and underlying epidotic grits. New divisional planes have consequently arisen, which are inclined at gentle angles to E.S.E. Thin pegmatites of quartz and felspar appear in the displaced sandstones and shales crossing the planes of schistosity. A high degree of metamorphism is likewise observable in certain outliers of the basal Torridonian beds at Loch nan Gillean and Loch na Leitire, east of the great crag of gneiss beyond Duncraig. (Sheet 71.) Above the Balmacara thrust-plane that stretches from the shore of Loch Alsh at Ard Hill north to near the head of Balmacara Burn, and thence in a winding course round Coille Mhor and Sgorr Beag to Gleannan Dorch, highly deformed Lewisian gneiss is observable, together with patches of epidotic grits and shales, which here and there have likewise undergone much alteration.

The position of the Moine thrust-plane is defined at certain places between Braeintra in Strath Ascaig and Kirkton of Lochalsh. Of special interest and importance is the evidence of the crushing and deformation of the siliceous schists above that plane.

At the western end of the section drawn in Fig. 55 the position is shown of the great fault (f) which has already been referred to as letting down the thrust Cambrian dolomites, limestones, and underlying quartzites against the undisturbed Torridon Sandstones of the Applecross region. This dislocation passes under the sea and runs down the length of Loch Kishorn. The heaped-up dolomites are in turn overriden by pipe-rock, fucoid-beds, and serpulite-grit, these being abruptly truncated by an intermediate displacement which, coming in advance of the Kishorn thrust, brings forward a small core of crushed gneiss and red sandy shales (Torridon). Eastwards the belt of inverted Torridon Sandstone, composed, as already indicated, of the Diabaig group (Ba), and inclined at gentle angles to E.S.E., is traversed by an east and west fault that runs along Glen More and shifts the outcrop of the Kishorn thrust-plane westwards to the sea-floor. (Sheet 81.)

On the west and south slopes of An Sgorr the black and grey shales and epidotic grits at the base of the Torridon series pass in inverted order underneath the Lewisian floor, which, not far above the line of junction, consists of a prominent sill of epidiorite and hornblende-schist (B^{a}), underlain in places by grey gneiss (A), mica-schists, and rusty-brown, slightly graphitic schists, recalling the types of rock that appear north of Loch Maree in the undisturbed area of gneiss. In Sheet 81 the development and distribution of this intrusive mass are shown. It ranges southwards to North Strome, near to which place it may be examined in some excellent exposures.

On the southern slope of An Sgorr the Lewisian rocks and the inverted Torridon Sandstone below them have been thrown into a gentle arch, indicative of the folding of the displaced materials after their inversion. Eastwards the grey gneiss and associated hornblende-schist are followed by masses of basic material with red pegmatites, which on the higher part of the eastern declivity are not much deformed. Towards Slumbay, however, the development of mylonites is well marked, both the grey acid gneiss and pink pegmatites showing fine flaser structure. The position of the Moine thrust probably lies here beneath the sea-level, as shown in Fig. 55. On Sgeir Chreagach, in the middle of Loch Carron, fine garnetiferous mica-schist appears, and on the east side of the loch granulitic, siliceous Moine-schists (M) are followed by a mass of reconstructed Lewisian gneiss (A). The granulitic hornblende-gneiss seems to occur here in the form of an arch, as the siliceous flagstones are met with higher up the slope.

The great fault in Loch Kishorn splits into several branches which skirt the southern shore of Applecross, and there produce marked brecciation of the unthrust members of the middle division of the Torridon Sandstone. East of this normal displacement in Loch Kishorn, the beds of arkose forming the Applecross group (Bb, Fig. 56), also the various sub-divisions of the Diabaig group (Ba^1 to Ba^4) met with in Sleat (Skye), can be traced succeeding each other, but in inverted order. They are finally surmounted by the Lewisian gneiss on Creag Dallag east of Duncraig. The higher Kinloch beds of Sleat (Ba^4) appear west of Reraig; the Beinn na Seamraig grits (Ba^3) on the promontory of Ardaniaskin and on the islands in Loch Carron; the Loch na Dal beds (Ba^2), the epidotic grits, and the local basement conglomerate (Ba^1) on the slope beneath

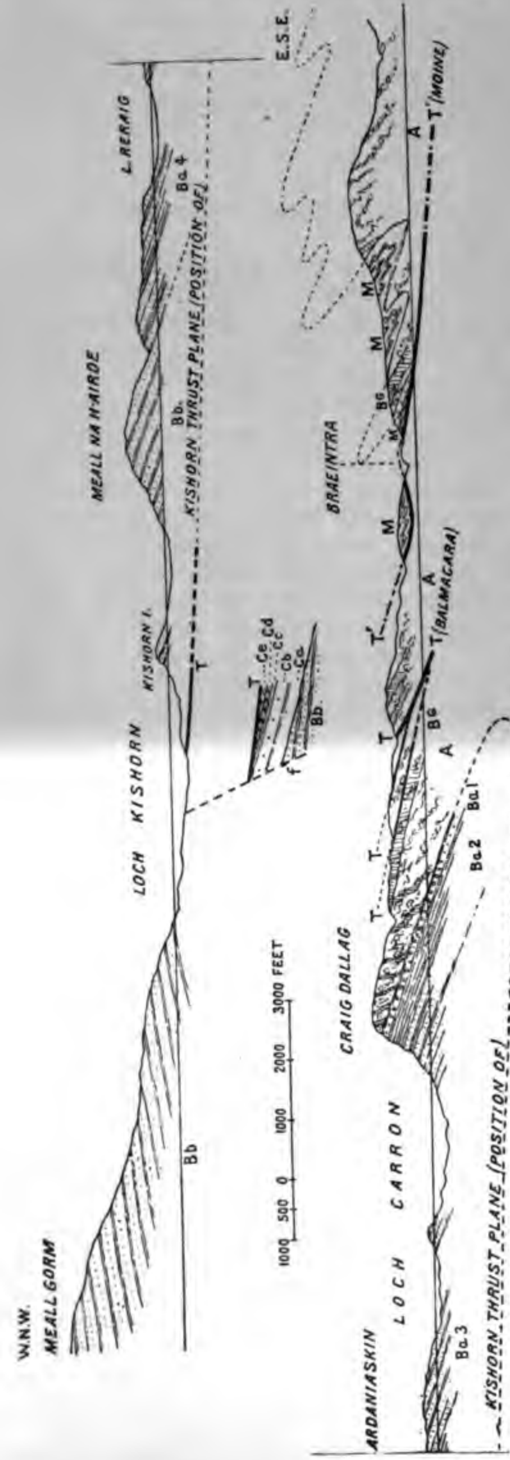

FIG. 56.—Section from Meall Gorm by Loch Reraig and Craig Dallag to Gleann Udalain.

A. Lewisian Gneiss. B^G. Epidiorite and Hornblende-schist in Gneiss. Ba^1 to Ba^4. Diabaig group (Torridonian).
Bb. Applecross group. Ca. Basal Quartzite (Cambrian). Cb. Pipe-rock. Cc. Fucoid-beds. Cd. Serpulite-grit. Ce. Limestone.
M. Eastern Schists. T. Thrusts. T'. Moine thrust. f. Fault.

Creag Dallag. Throughout this line of section there is a persistent dip to E.S.E. at gentle angles. Though flaser structure is apparent in the grits on Ardaniaskin, the deformation becomes much more pronounced near the overturned floor of Lewisian rocks, where the epidotic grits, the basal conglomerate and gneiss have acquired common planes of schistosity inclined to E.S.E.

Eastwards from the inverted base-line of the Torridon Sandstone flaser-structure decreases. Granulitic gneiss of the Meall Riabhach type (Loch Maree), including bands of hornblende-schist, occur on the ridge, and near the south-east limit of this mass the large sill of hornblende-schist (B^{o}) appears as the southern prolongation of that on An Sgorr referred to in the previous section. Mica-schists are not found here in association with this intrusive sheet, but east of Port a' Chuillin and about a mile west of Stromeferry they are met with on the shore. In the railway cuttings west of Stromeferry Station fine examples are seen of phacoidal structure in the pegmatites and basic gneiss. (See Plate XXIX., Part I., Chap. XIV.)

The sill of hornblende-schist is truncated by a well-marked thrust with a low dip, which brings forward a mass of highly-sheared platy gneiss. A second line of disruption supervenes, above which the Lewisian rocks still show some of their original characters, and further east a third displacement (the Balmacara thrust) has driven westwards some intensely-sheared gneiss, to be referred to in the sequel.

West of Braeintra, in Strath Ascaig, the plane of the Moine thrust is well exposed in a little side stream on the hill-slope, where an outlier of siliceous schist rests on deformed gneiss. Here the ordinary structures of the Moine-schists have been broken down by the post-Cambrian movements. The main outcrop of the Moine thrust-plane lies not far to the east. It is worthy of note that three-quarters of a mile south of Braeintra, at the bridge by the side of the road, an epidotic schistose grit appears at the inverted junction of the siliceous Moine-schists with the granulitic biotite gneiss of Lewisian age. Beyond the narrow belt of quartzose flagstones overlying the main outcrop of the Moine displacement outliers of Moine-schist (M) may be observed within the area of granulitised Lewisian gneiss (A). (Fig. 56.)

East of the headland of An Dubh Aird, at the mouth of Loch Carron, all the Torridon strata are inverted (Fig. 57). The axial line along which the inversion begins is situated among the members of the Applecross group (Bb), some of which have a normal dip to the west, while others are inclined to the east. As those with an eastward inclination are followed inland they are seen to pass in inverted order beneath the Diabaig group (Ba). The zone of Kinloch beds (Ba^4) is developed round the shores of the bay between Plockton and Duncraig, whence it extends eastwards beyond the mansion of Duncraig. These are followed in inverted order by the other sub-divisions of this lowest Torridonian group (Ba^3 to Ba^1), till, on the bold escarpment of Carn

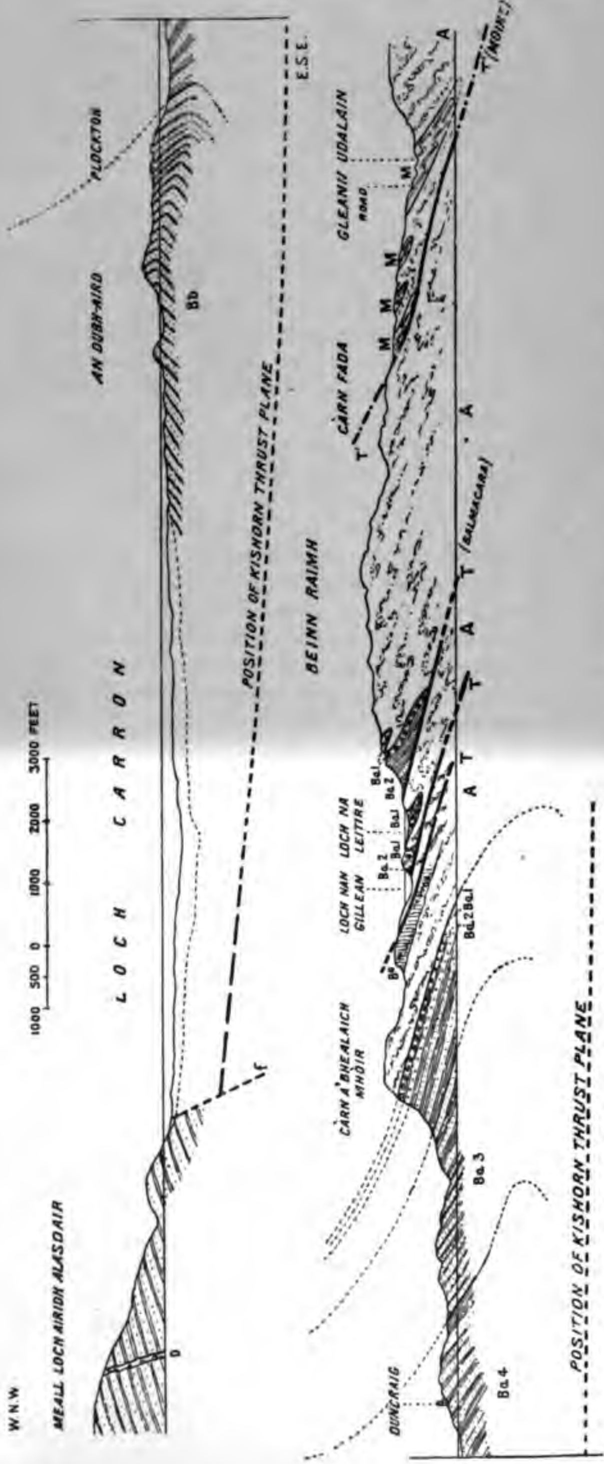

FIG. 57.—Section from Loch Carron by Plockton and Beinn Raimh to Gleann Udalain.

A. Lewisian Gneiss. B^G. Epidiorite and Hornblende-schist in Gneiss. Ba^1 to Ba^4. Diabaig group (Torridonian). Bb. Applecross group. M. Eastern Schists. D. Tertiary Dyke. T. Thrusts. T'. Moine thrust. f. Fault.

a' Bhealaich Mhoir, the basal conglomerate (Ba^1) is overlain by grey granulitic gneiss (A), on which it normally rests. The amount of deformation at this place is much less than that at Fernaig, already described. Beyond the gneiss lies the sill of hornblende-schist (B^q), previously referred to in this chapter, which is cut off by a thrust that brings forward platy crushed gneiss. Not far to the east a second thrust supervenes, which has driven westwards a slice of Lewisian gneiss with small outliers of the basal members of the Torridon Sandstone (Ba^1, Ba^2), showing a high degree of metamorphism. The general strike of the foliation of the Lewisian series here is north-west and south-east, but near the lines of disruption it roughly coincides with their trend. The gneiss is massive and hornblendic, with bands of epidiorite. The patches of inverted Torridon strata lie in several folds, two of which appear in the line of section. (Fig. 57.) They comprise the basal conglomerate, epidotic grits, together with dark shales and flaggy grey siliceous sandstones of the Loch na Dal group of Sleat. These rocks show flaser-structure, peripheral granulitisation of the grains, and a development of sericitic mica. They are visible on the south-east shore of Loch nan Gillean and on the south side of Loch na Leitire, three miles north of Kirkton of Lochalsh. (Sheet 81.) About 200 yards east of the latter lake the pebbles in the basal conglomerate have been flattened and elongated.

About 100 yards south of Loch na Leitire the outcrop of an important thrust-plane (Balmacara) has been laid open in a small burn, where the grey flaggy beds of the Diabaig group are superimposed on sheared gneiss. On the cliff south of that lake the black shales of the Loch na Dal group are surmounted by the epidotic grits and basement conglomerate that pass, in inverted order, beneath the overturned Lewisian floor (A). Here the thrust Torridonian strata show a considerable degree of alteration. Still further to the east along the same line of section a remarkable development of intensely-sheared gneiss appears on Beinn Raimh. In this Lewisian mass the original structures have been almost wholly effaced, its band of acid and basic rock with pegmatites being now represented by red, grey, and green striped mylonites. On the eastern declivity of the same hill these rocks are truncated by the Moine thrust (T′), which has here carried westwards four inverted folds of siliceous schist (M, M) with intervening bands of gneiss (A). The type of Lewisian rock in these intervening arches is a granulitic, epidotic, hornblende-biotite gneiss with large lenticles of hornblende-schist. At the eastern margin of the third infold of siliceous schist and at the western edge of the fourth belt, exposed in Gleann Udalain, a conglomeratic rock makes its appearance, having a holo-crystalline, micaceous, and hornblendic matrix, and containing pebbles of quartz and of an epidotic gneiss like the underlying Lewisian type.

At Erbusaig, on the west coast of the peninsula between Loch Carron and Loch Alsh, and on the outlying islands, the beds of the middle division of the Torridon Sandstone have a normal inclination to the west. Further east lies the axial north and south line of inversion, east of which, for a distance of four miles, the Torridonian strata are inverted. The arkose of the Applecross group (Bb), extending eastwards to near Loch Scalpaidh, is followed eastwards in inverted order by the members of the Diabaig group (Ba^4 to Ba^1), which, thrown into gentle anticlines and synclines, seem so regular and undisturbed as to make it at first hardly credible that they can be in reality all upside down. They are eventually abruptly truncated by the Balmacara thrust, which has driven some intensely-deformed gneiss over the sheared Beinn na Seamraig grits and sandstones. The deformation that accompanies this plane of movement is well exposed on the shore south of Ard Hill and on the wooded hill north of Balmacara Hotel. The original structures have been here so completely effaced that it is difficult to determine at what point the line of disruption should be drawn. (Fig. 58.)

Beyond this mass of flaser-gneiss which forms the high ridge of Kirkton Hill the Moine thrust supervenes near Auchtertyre. This gigantic displacement has here brought westwards a belt of siliceous (Moine) schists (M), from 300 to 500 yards broad, well exposed in the burn that drains the hollow between Kirkton and Auchtertyre hills. They are interleaved in places with thin bands of hornblende-biotite-schist, and dip at gentle angles to E.S.E. Near the thrust-plane their structures have, as usual, been crushed and deformed by the post-Cambrian movements. Along their eastern margin they are overlain by flaggy biotite and hornblende-gneisses with early basic masses of Lewisian type, and they pass transgressively across the acid and basic rocks. It will be observed that in the Loch Alsh district the intercalation of masses of undoubted Lewisian rocks above the Moine thrust-plane reaches a remarkable development, and that a considerable body of these rocks lies below that plane within the sphere of movement of the Balmacara thrust. It is to be remembered also that deep below all these rocks and beneath the inverted Torridonian series the Kishorn thrust-plane has its place. (See Fig. 57.)

CHAPTER XXXIX.

STRUCTURE OF THE PENINSULA OF SLEAT AND PART OF STRATH, SKYE.*

The structural features of the district of Loch Alsh, described in the previous chapter, are prolonged into Skye, where some of them become more strikingly developed. The much greater thickness of the Torridonian series in this island than on the mainland to the north of Loch Alsh has doubtless led to a striking manifestation of the characters of this belt of complication among the members of that series. The great Torridonian inversion so clearly displayed on the opposite mainland crosses into the district of Sleat, where also, as already remarked, overfolding of the strata appears to be more prevalent than reversed faults in front of the great thrusts. The areas occupied by displaced Lewisian rocks in Skye are of comparatively small extent. The Cambrian quartzites and lower limestones in the districts of Sleat and Strath have, certainly in great part and perhaps wholly, been displaced and driven into their present positions by some of the great westward movements of the terrestrial crust. The great Moine thrust, which in the preceding chapters has been followed southwards from the north coast of Sutherland, crosses over into Skye and runs through the southern part of Sleat to the southern extremity of the island, bringing with it slices of the Lewisian rocks and its characteristic gneissose flagstones and siliceous schists. The structure of this portion of Skye will be best understood from the series of horizontal sections described in the present chapter, which are arranged in topographical order from north to south.

The section in Fig. 59 shows the general grouping of the rocks near the north end of Sleat. It will be observed that all the rocks here represented in the Skye portion of the section are Torridonian, with the exception of some dykes and a small patch of mylonised rocks which appear from under the sea at Dun Ruaige. Although the Torridon Sandstones are here in some places but little altered, it is nevertheless certain from what is seen near Broadford (Fig. 61) and Ord (Fig. 62) that they have all been thrust forward from the south-

* By C. T. Clough. The district described in this chapter is comprised in Sheets 61 and 71 of the map of Scotland, on the scale of 1 inch to a mile.

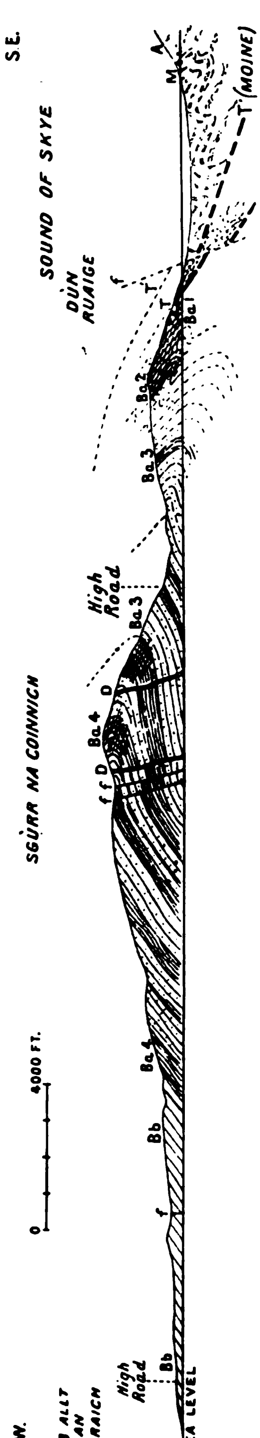

FIG. 59.—Section across the north end of Sleat, Skye, from the coast at Ob Allt an Daraich across Sgùrr na Coinnich to the Sound of Skye at Dùn Ruaige.

A. Lewisian Gneiss. Ba^1. Epidotic Grits (Torridonian). Ba^2. Loch na Dal Beds. Ba^3. Beinn na Seamraig Grits. Ba^4. Kinloch Beds. Bb. Applecross group. M. Moine Schists. D. Tertiary Dykes. T. Thrust. T'. Moine thrust. f. Faults.

east over other rocks, consisting in part of Cambrian quartzite and limestone. They have been carried *en masse* with comparatively little disturbance, excepting near the axial plane, inclining gently south-east, of the great Loch Alsh inversion. Most of the strata on the top and to the east of Sgùrr na Coinnich lie in the upper limb of this fold, and in reversed position.

The red and chocolate arkoses of the Applecross division of the Torridon series (Bb) appear at the north-west end of the section, underlain in a south-easterly direction by the different divisions of the Diabaig group—the Kinloch beds (Ba^4), the Beinn na Seamraig grits (Ba^3), the Loch na Dal shaly series (Ba^2), and the epidotic grits (Ba^1). The arkoses and most of the Kinloch beds lie in their normal order in the lower limb of the great fold and dip north-west at angles ranging from 20° to 50° The lower portion of the Kinloch division, however, together with a great part of the Beinn na Seamraig grits, as well as all the Loch na Dal beds and epidotic grits, are included in the upper or inverted limb of the fold. Since the inclination of the axial plane of this fold is not so great as that of parts of the south-eastern slope of Sgùrr na Coinnich, strata which lie in the lower limb of the fold crop out in this valley to the south of that hill and in their original order. Although some of them appear in the figure as if nearly flat, they have really a dip to north-east almost at right angles to the line of section. A north-easterly dip can also be observed for some distance south-west of the line of section. None of the beds which dip north-east lie far from the axial plane of the great fold, and it seems more probable that their inclination is connected with the production of the great fold rather than with any cross fold of later date.

The Applecross arkoses at the north-west end of the section are in a much less altered condition than the Torridonian rocks at the south-east end. They either display no cleavage or only a very weak one, while in the rocks at the opposite end the cleavage planes are strongly developed and often show sericitic lustre, as well as a considerable elongation of their large clastic grains, and the presence of many thin and short quartz-felspar veins. Besides this increase of alteration in a south-easterly direction, it has been ascertained that when the rocks of Sleat are traced along their strike from south-west to north-east the Torridonian series displays an augmented degree of alteration towards the north-east. Some of the Applecross beds on the north-eastern side of the line of section contain thin veins, usually less than an inch thick but sometimes six inches, of quartz, felspar, and chlorite. The lower beds of the Beinn na Seamraig grits are frequently crossed by micaceous foliation planes. In the Loch na Dal shales near Dun Ruaige the bedding planes are repeatedly crossed by similar lustrous foliation planes. On the sides of Loch na Dal, however, cleavage planes cannot always be observed, and when present are never lustrous.

On either side of Dun Ruaige the epidotic grits have been thrown into small folds with axial planes that hade to south-east. In many places these strata have also been foliated parallel to the axial planes of the plication. They must lie considerably above the axial plane of the great inversion. The small folds may have been produced during the thrusting forward of the mylonised rock of Dun Ruaige. In some places the beds have been folded by folds with steep pitch after they were already foliated. Many of the clastic grains or pebbles in the epidotic grits are so large that any deformation in them is readily perceived. Near the line of section, and all the way between Dun Ruaige and a point about three-quarters of a mile W.S.W. from the foot of Allt Thuill, deformation of these constituents is very evident, the long axes of the grains being parallel to each other and often three or four times as long as the other axes. The foliation-planes along which the elongation occurs sometimes cross the bedding at considerable angles, so that the pebbles are now inclined steeply to the planes on which they were originally deposited.

The Torridonian beds are overlain at Dun Ruaige by a patch of mylonised rock which has probably been thrust over them, and which may have been formed from Lewisian gneiss. The oncoming of the Moine-schists and the Lewisian gneisses associated with them is concealed under the Sound of Skye.

These rocks, however, are probably separated from the rock of Dun Ruaige by the Moine thrust, although along the line of section this thrust is perhaps itself hidden by a fault with a large south-easterly downthrow. The mylonised rock of Dun Ruaige only extends along the coast for 250 yards, with a breadth of not more than 70 or 80 yards. It is in a very different state from the epidotic grits near it. Though these grits have been much deformed, and partly recrystallised, their original bedding remains always distinct. In the Dun rock, on the other hand, no original banding can be recognised, and stretching is much more prominently shown than in any of the Torridon rocks. If the positions of the grit and the mylonised rock were supposed to be reversed, and if before reversal the grit lay unconformably upon the other rock, it would be necessary to suppose that other rock to have been already in a mylonised condition before the deposition of the grit. It seems more probable that between the grit and the Dun rock the plane of some great thrust must intervene. The Dun rock is for the most part a fine flaggy greenish-grey rock, with a sericitic or chloritic lustre on the parallel splitting planes. It contains many thin folded reddish veins of quartz and felspar, some of which are unsheared, while others have undergone the same mylonising as the rest of the rock. Many of the folds have closely appressed limbs, and axial planes inclining gently to E.S.E.

The fault which is believed to bring on at this part of the Skye coast the Moine-schist and the Lewisian gneiss associated with it, runs in a north-easterly direction with a hade and downthrow to south-east, anu is seen on the north side of Glenelg Bay, where it has effected a surface displacement of a mile in one of the boundary lines between the schist and the gneiss. Along the line of section the first rocks met with on the south-eastern shore of the Sound of Skye are granulitic Moine-schists (M) of a siliceous type. Further to the south-east these schists pass under a band, twenty to thirty feet thick, of garnetiferous mica-schist, which in turn is succeeded on the south-east by a coarsely granulitic biotite gneiss. The superposition of the gneiss over the Moine-schist in this section is no doubt due to folding and cannot be taken to indicate the original relations of these rocks. In many adjacent places the gneiss dips below the Moine-schist.

Another section taken along a line three miles to the south-west of that described is given in Fig. 60. Here all the sedimentary rocks, except those at the base of the Mesozoic formations (*f*), which appear at the north-west end of the section around Skulamus, are Torridonian. They include the Applecross arkoses (Bb), Kinloch beds (Ba^4), Beinn na Seamraig grits (Ba^3), Loch na Dal beds (Ba^2), and epidotic grits (Ba^1). All these strata form part of the great thrust mass already described; but, except near the south-eastern end of the section, they have retained their original order, the younger beds

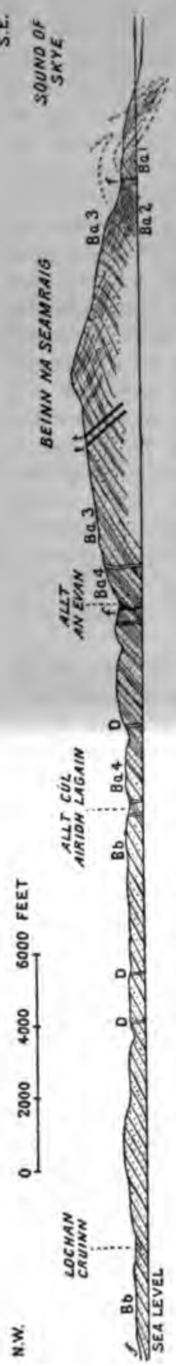

FIG. 60.—Section from near Skulamus across Beinn na Seamraig to the Sound of Skye.

Ba[1]. Epidotic Grits (Torridonian). Ba[2]. Loch na Dal Beds. Ba[3]. Beinn na Seamraig Grits. Ba[4]. Kinloch Beds. Bb. Applecross group. *f*. Trias. D. Tertiary Dykes. t. Minor thrusts. f. Faults.

dipping over the older in a north-westerly direction at angles of between 30° and 50°. The last of the great Loch Alsh inversion is perhaps indicated along the south-east flank of Beinn Seamraig. A little south-west of the line of section the sandy shales of the Kinloch sub-division are excellently exposed, but show no cleavage. Further south-east some of the Beinn na Seamraig beds are crossed by cleavage planes dipping to south-east or E.S.E., between 48° and 65°.

Along certain lines a little north-west of Beinn na Seamraig the grits have been crushed, probably by thrusts, into finely-laminated halleflinta-like rocks. Two of these lines (t t) are indicated in the section, but how far they alter the position of the rocks is not known. The Loch na Dal beds and the epidotic grits at the south-east end of the section are much folded and altered, and probably lie near the axial plane of the large fold shown in Fig. 59, and not far below some other higher dislocations, including the Moine thrust. On the coast their parallel splitting planes are slightly lustrous, but not so much so as near Dun Ruaige and Kyle Rhea. The pebbles and clastic grains in the grits are conspicuously elongated, and where the planes on which the grains are observed dip south-east the direction of elongation is generally nearly east and west. The chief folds in these altered rocks are, on the north-west side, a rather wide and gentle anticline, with the limbs dipping in opposite directions, and on the south-east side an isoclinal syncline, with both limbs dipping south-east.

The next section (Fig. 61) drawn at a distance of three miles from the last across Strath and Sleat, so as to take in one of the chief areas of Cambrian strata in Skye, shows the reality of the displacement of all the Torridonian rocks of this region. Its most striking feature is the appearance of a mass of Cam-

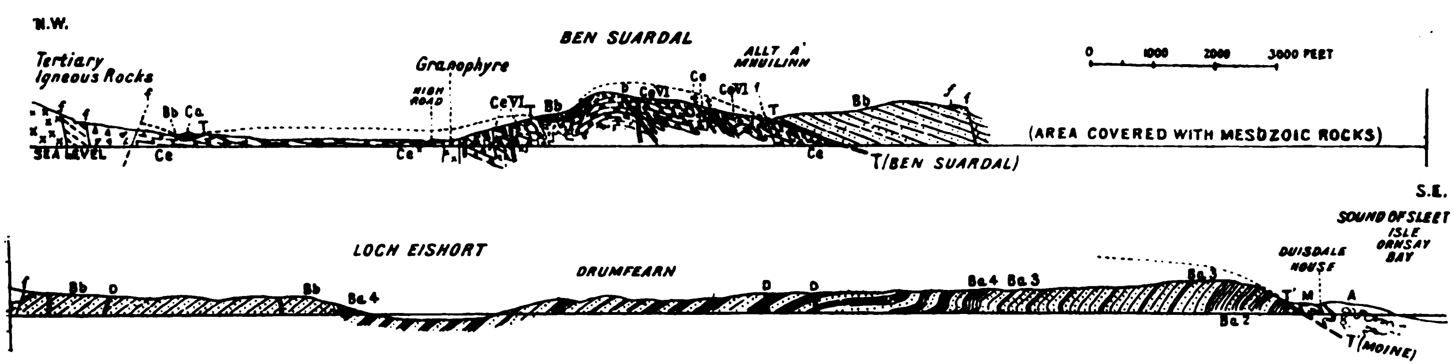

FIG. 61.—Section from the foot of Beinn na Caillich, Broadford, across Strath, Loch Eishort, and Sleat to Duisdale House, on the Sound of Sleat.

A. Lewisian Gneiss. Ba². Loch na Dal Shales (Torridonian). Ba³. Beinn na Seamraig Grits. Ba⁴. Kinloch Shales. Bb. Applecross group. Ca. Basal Quartzite (Cambrian). Ce. Beinn an Dubhaich and Strath Suardal groups. Ce VI. Ben Suardal group. M. Moine Schist. *f*. Trias. D. Tertiary Dykes. T. Ben Suardal Thrust. T'. Moine thrust. t. Minor thrusts. f. Faults.

brian limestone (Ce and Ce VI.) emerging from beneath the Applecross grits (Bb), which have been pushed forward along a major thrust-plane. This plane can best be seen near Ben Suardal, where it has been folded into an anticline with an axial plane striking to N.N.E. and hading to south-east. It may be conveniently called the Ben Suardal thrust.* In Allt Beinn Deirge, nearly a mile north-west from Ben Suardal, a small patch of Applecross grit, surmounted by the unconformable basal quartzite, is seen to rest almost horizontally on Cambrian limestone, the same thrust-plane intervening between the two rocks. This thrust-plane is also recognisable on the south-eastern slopes of Creag Strollamus, about two miles and a quarter slightly west of north of the place where the line of section crosses Allt Beinn Deirge, so that in this district the breadth of the belt of Post-Cambrian complication must be at least nine miles and a half.

The Cambrian limestones are sharply folded and crossed by minor thrust lines, and they probably all lie on some great thrust-plane not exposed at the surface. Most of the rocks between them and the Moine thrust at the east end of the section are Torridonian. But among them lies a synclinal basin of Mesozoic rocks (*ff*, left blank in Fig. 61), which were deposited long after the thrust-movements had ceased. East of Allt a' Mhuilinn the Ben Suardal thrust is hidden beneath Applecross grits, and never reappears further eastward along the line of section. Unless it should crop up beneath the Mesozoic basin—which seems hardly likely—it must underlie all the Torridonian beds in the section. It may possibly be a continuation of the folded thrust of Sgiath-bheinn Tokavaig (Figs. 62 and 64). A fold which affected the Ben Suardal thrust also bent the Mesozoic beds which circle round the north end of this hill. The whole of the folding exhibited by the thrust may not be so late as these beds, but most of it must be, for the beds in each limb of the anticline dip almost the same as the thrust.

The calcareous rocks under the Ben Suardal thrust comprise the Ben Suardal, Strath Suardal, and Beinn an Dubhaich zones. In many places the rocks are saccharoidal, and crowded with needles of tremolite and prisms of malacolite developed by contact metamorphism near the large Tertiary igneous masses. The Ben Suardal thrust-plane and the overlying Applecross grits are never isoclinally folded, but the limestones often are, and they must have been folded either before, or at the same time as, the Torridon rocks were being thrust over them. The later movement which folded the thrust-plane must, however, have also bent the axial planes of the isoclinal folds. Various thrust-like lines have been noticed in the limestone, and two of them are shown in the section to the north-west of Allt a' Mhuilinn. In

* The disturbed condition of the beds on Ben Suardal was described by Sir A. Geikie ("On the Age of the Altered Limestones of Strath, Skye." *Quart. Jour. Geol. Soc.*, 1888, vol. xliv., p. 70). He inferred that the whole of the limestone on this hill has been pushed westward.

a few places the cherts and fossils in the Ben Suardal limestone have been considerably deformed. On the north-west side of Loch Lonachan, about 700 yards S.S.W. of the outlet, the small black cherts have been broken and dragged into trains of small granules in a north-west direction, at right angles to the strike, and some of the fossil *Maclurea* have been elongated in the same direction.

That the inclination of some parts of the north-west limb of the Ben Suardal thrust-plane must be rather steep is indicated near a limestone scar which faces westward on the east side of the thin patch of Applecross grit on the western slope of Ben Suardal. The inclination of the thrust-plane must here be steeper than the face of the scar. The south-east limb is broken in places by a fault, or several parallel faults, with a downthrow towards south-east. Crush-breccias appear along the later faults, often with a breadth of several feet and nearly vertical, whereas along the thrust-plane no such rock exists nor any marked sign of disturbance. The Applecross grits above the thrust appear to be remarkably little disturbed. The bedding is, however, less distinct, and joints are more abundant than in most unthrust rocks. There is sometimes, also, a slight brecciation and alteration of colour, from red to pale buff, for a little distance above the thrust.

From the evidence supplied by the exposures near Creag Strollamus, it is probable that Applecross grits in a thrust condition overlie high zones of the Cambrian limestone for a distance from E.S.E. to W.N.W. of at least three miles, and that the grits near this Creag have been thrust at least as far as the sum of this distance and the distance required to get in the strata which in the undisturbed sequence come between these grits and the most south-easterly portion of the limestone exposed beneath the thrust-plane. These strata include some portion, but perhaps not much, of the Applecross grits, all the quartzite, fucoid-beds, and serpulite-grit, and four or five of the lowest divisions of the limestone. If these members of the Cambrian series succeed each other in their normal order to the south-east of the limestone, and have the same dip as at Ord in Sleat, then the movement along the thrust-plane cannot have been less than three miles and three-quarters, but it may, however, have been much more.

South-east of the tract of Mesozoic rocks the Applecross grits (Bb) emerge at the surface with a north-westerly inclination of 25° to 50°, followed by the underlying Kinloch shales (Ba^4), which continue for two miles as a belt which owes its breadth chiefly to the gentle dip which occasionally prevails, and to local folding. Although towards the south-east these shales are more steeply inclined and are sometimes vertical or even reversed, none of them are appreciably altered, nor do they usually show any cleavage. They are succeeded by the Beinn na Seamraig grits (Ba^3) and the Loch na Dal shales (Ba^2), but before the base of these shales is reached a line of crush, running north-east and hading towards south-east, brings on the Moine-schist (M). The inclination of this crush is here steeper than that usually presented by the Moine-thrust, but it decreases in a south-westerly direction. The band of Moine-schist next the Torridon rocks thins out in the same direction, and its place is taken by the Lewisian gneisses and hornblende-schists.

In Allt Duisdale a sheet of red lamprophyre has been injected along the Moine-thrust. Since parts of it have been crushed into a stiff grey crush-clay, there appears to be evidence here of at least two periods of movement along the thrust—one that gave rise to the line of fracture along which the lamprophyre was intruded, and another of later date which crushed the lamprophyre. In the gneiss above the thrust-plane other crushes appear parallel to the main thrust, and the earlier crystalline structure of the gneiss has been partly broken down. A little further south-west, across a large fault, a band of siliceous Moine-schist lying just above the thrust-plane has likewise had its earlier crystalline structure broken in places.

A good junction between the Moine-schists and the gneiss rocks may be seen on the shore in the south-eastern part of Camas Croise. Although no signs of unconformity are there visible, yet in the adjacent area bands in the gneiss strike at a gentle angle against the junction, and in different places vary in distance from it.

In the section drawn in Fig. 62 two major thrust-planes are shown to have been folded into anticlines, the axes of which strike N.N.E. The higher of the two is well seen a little south of the line of section on the west side of Sgiath-bheinn Tokavaig, and may be called the Sgiath-bheinn Tokavaig thrust. The lower line of dislocation, which is nearly always distinct, may be named after Sgiath-bheinn an Uird, a hill composed of rocks that lie beneath it.

These two thrusts and the rock-masses below are exposed on the south-western or upthrow side of a large fault which runs in a N.N.W. direction from Ob Snusaich, in the Sound of Skye, past the west side of Ben Vokie, and through Loch an Eilean. On the north-west side of Loch Eishort this fault has thrown down the conglomerates at the base of the Mesozoic rocks in a north-easterly direction between 500 and 600 feet, and to the south-east of the loch it has depressed the older rocks in the same direction. Hence neither of the thrust-planes can be seen in that part of Skye which lies to the north-east of the fault between Loch an Eilean and Ob Snusaich. As already stated, the Cambrian limestones in Ben Suardal also underlie a great folded thrust-plane, which may possibly be a continuation of that on Sgiath-bheinn Tokavaig, but it has been folded along an axis which lies two or three miles further to the north-west.

Along the line followed by this section all the rocks exposed beneath the Sgiath-bheinn an Uird thrust are Cambrian, but a little further south Torridon rocks are also visible, sometimes in a reversed position above the quartzite. More than half of the

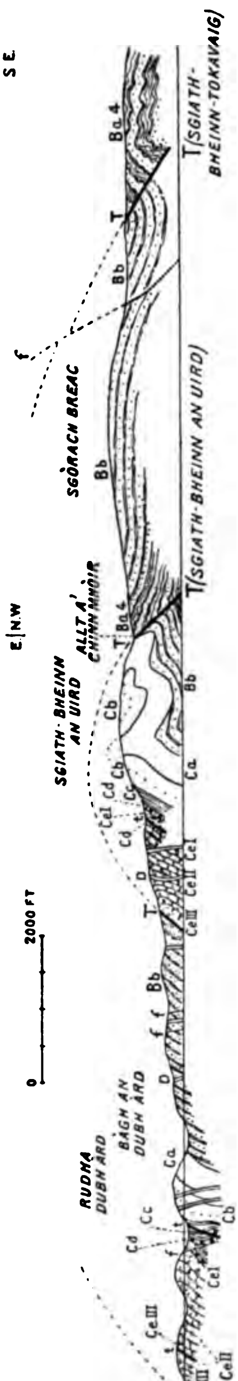

FIG. 62.—Section from Loch Eishort over the north side of Sgiath-bheinn an Uird.

Ba⁴. Kinloch Beds (Torridonian). Bb. Applecross group. Ca. Basal Quartzite (Cambrian). Cb. Pipe-rock. Cc. Fucoid-beds. Cd. Serpulite-grit. Ce I. Ghrudaidh group. Ce II. Eilean Dubh group. Ce III. Sailmohr group. D. Tertiary Dykes. T. Thrusts. t. Minor thrusts. f. Faults.

ground covered by Cambrian strata is occupied by the quartzite, which has been thrown into folds with axial planes hading to the south-east. The top of the quartzite (Cb) generally dips steeply towards W.N.W. under the fucoid-shales (Cc), followed by the serpulite-grit (Cd) and the Ghrudaidh limestone (Ce I). The grit is repeated by a nearly vertical thrust, and most of the beds are inclined at high angles, but they have been bent by minor folds with nearly horizontal axial planes, whereby the outcrops along the same strike are made to dip towards W.N.W. or E.S.E. alternately. West of the Ghrudaidh limestone comes the Eilean Dubh sub-division (Ce II.), succeeded by a small portion of that of Sailmhor (Ce III.).

It is probable that originally the Sgiath-bheinn an Uird thrust-plane had a gentle inclination towards the south-east, as is the case with so many of these thrusts, and that the beds below it were once arranged in a set of folds with axial planes hading to the south-east. Thereafter the whole of the rocks below the western limb of the thrust, as well as this portion of the thrust itself, may be supposed to have been bent, so as to dip for the most part in an opposite direction to their first inclination. Besides the minor thrust which repeats the serpulite-grit there may be others which are not distinct. A little south of the line of section other thrusts do appear, some of which are of considerable importance, and are indicated in Fig. 63.

Below the Sgiath-bheinn an Uird thrust the strata are not cleaved, nor is there any noticeable distortion of the pipes in the pipe-rock. In considerable areas of the quartzite, however, the bedding is obscured by joints and planes of crush which present no clear general strike. The crushed surface of quartzite under the south-eastern limb of the thrust-plane makes a conspicuous scar on the east side of the hill. It generally strikes to north or N.N.E., and is inclined towards east or E.S.E. at angles of 50° or more, but along the line of section its inclination is lower than usual. The material that forms the scar is often brecciated and contains broken pieces of quartzite, some of which are rounded and look like pebbles. A crushed face of serpulite-grit, exposed just below the north-western limb of the thrust-plane rather more than a quarter of a mile south-west of the line of section, inclines at 50° in a north-westerly direction.

Near the north-western limb of this thrust various considerable patches of a curious siliceous rock overlie, or crop out in, the Sailmhor, Eilean Dubh, and Ghrudaidh limestones. Some parts of this rock look rather like portions of serpulite-grit, though they never contain clastic grains. Other parts are cherty, though some of the largest patches occur near horizons which are normally almost free from chert. It seems probable on the whole that the rock is a vein rock—perhaps formed by solutions percolating downwards from the formerly overlying thrust-plane.

The rocks that lie between the two thrusts of Sgiath-bheinn an Uird and Sgiath-bheinn Tokavaig are chiefly Torridonian, but in the north-western limb of the anticline a strip of unconformable Cambrian strata makes its appearance. It includes all the groups between the basal quartzite (Ca) and the Sailmhor (Ce III.), or (perhaps in one place) the Sangomore limestone. The Torridonian rocks belong chiefly to the Applecross group (Bb), but comprise also shales and grits which may form the top of the Kinloch division, and which in Allt a' Chinn Mhoir are a good deal confused. The Applecross grits above the north-western limb of the Sgiath-bheinn an Uird thrust-plane generally dip north-west at nearly the same angle as that limb. If this part of the thrust-plane were bent into its probable original position, so as to incline gently to south-east, the overlying grits and most of the Cambrian rocks which rest upon them would also be made to incline gently south-east.

A little to the west of the Rudha Dubh Ard quartzite, on the shore south of the line of section, a nearly vertical thrust repeats a part of the fucoid-shale and serpulite-grit, and probably several other more obscure thrusts are likewise present there. The Grudaidh, Eilean Dubh, and part of the Sailmhor limestone are well exposed in the islands of Loch Eishort, at the west end of the line of section, generally striking slightly west of north, but varying continually in the direction of their dip owing to the presence of some small folds with nearly horizontal axial planes. In the western island the junction of the Eilean Dubh and Sailmhor limestone is repeated by a steep thrust.

The rocks that come above the Sgiath-bheinn an Uird thrust have not in most places been so much folded or crushed as those underneath, and, like them, they are never cleaved. Near the north-western limb of this folded thrust-plane the Applecross grits are here and there changed in colour from red to pale-grey, while close to the overlying Sgiath-bheinn Tokavaig thrust they have also in places assumed a greenish-grey hue for a few inches, or are crossed by thin quartz-veins without any general direction.

The dip of the south-eastern limb of the anticline of the Sgiath-bheinn Tokavaig thrust-plane is E.S.E. at 32° or 33°. The opposite limb is hidden under Loch Eishort, but in its course northward from Ord Bay it must have a direction slightly west of north, for otherwise it would cross, or pass east of, the western island shown in the section. The rocks above the south-eastern limb of this thrust-plane consist of shales and fine-grained grits belonging to the Kinloch division (Ba^4). Owing to their strong lithological difference from the red Applecross grits (Bb), which on the west side of them lie below the thrust, the thrust-plane is here easily traced in spite of some faults. Near it the Kinloch beds are much shattered and contorted along axial planes that hade to south-east, but no cleavage is here discernible parallel to these planes. A little further south-east, however, some shales are crossed by a cleavage the planes of which incline slightly south of east from 50° to 60°.

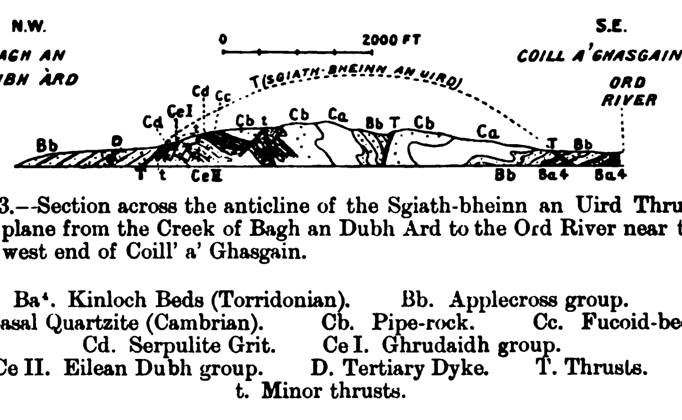

FIG. 63.—Section across the anticline of the Sgiath-bheinn an Uird Thrust-plane from the Creek of Bagh an Dubh Ard to the Ord River near the west end of Coill' a' Ghasgain.

Ba^4. Kinloch Beds (Torridonian). Bb. Applecross group.
Ca. Basal Quartzite (Cambrian). Cb. Pipe-rock. Cc. Fucoid-beds.
Cd. Serpulite Grit. Ce I. Ghrudaidh group.
Ce II. Eilean Dubh group. D. Tertiary Dyke. T. Thrusts.
t. Minor thrusts.

Fig. 63 gives a section across a complicated portion of the rock-mass which underlies the Sgiath-bheinn an Uird thrust a little south of the line of section in Fig. 62. The south-eastern portion of this mass is a continuation of that shown under this thrust in the last section. It is separated from the north-western portion by a distinct crush or thrust (T) which runs in a general north and south direction; the rocks on its western side being Applecross grits with some beds of shale (Bb), while those on the other side consist of a broad exposure of pipe-rock (Cb). This line of rupture does not seem to affect the rocks above the Sgiath-bheinn an Uird thrust. It twists more sharply than most normal faults of later age than the great post-Cambrian movements. On its north-western side the Applecross grits are succeeded by Cambrian strata extending up to the Eilean Dubh limestone (Ca to Ce II.), all generally in a reversed position and crossed by various thrusts. The plane of one of these dislocations, at the base of the serpulite-grit, must have been folded before the production of the Sgiath-bheinn an Uird thrust.

The serpulite-grit on the north-west side of the fucoid-shale forms part of an anticline with its axial plane striking to N.N.E. and hading to south-east. In all parts of this anticline the beds which comprise the Ghrudaidh and part of the Eilean Dubh limestone, as well as the serpulite-grit, are reversed. The Ghrudaidh limestone is often absent either wholly or partly, in consequence of a minor thrust at the base of the serpulite-grit, which has been folded together with the grit. The beds at the south-western apex of the anticline are cut by a straight portion of the Sgiath-bheinn an Uird thrust-plane, so that the anticline must have been formed before this plane was folded. Before the later folding the limbs of the anticline cannot have been inclined as they are now, and at that time the beds in the south-eastern limb of the thrust were perhaps not reversed. Near the south-western apex of the anticline the outcrop of the fucoid-shale is so unusually narrow that perhaps the pressure below the Sgiath-bheinn an Uird thrust may have squeezed out some of the shale from between the more massive serpulite-grit and quartzite. Some parts of the quartzite seem also to be missing here. Along all the exposed portion of the north-western limb of this little anticline the serpulite-grit is overlain by the Torridonian (Applecross) grits. About 60 yards north from the line of section the crushed face of serpulite-grit just under the Sgiath-bheinn an Uird thrust-plane inclines at 42° towards north-west. The position of the south-eastern limb of the thrust is not quite clear in the line of section, but it must have Applecross grits on both sides of it.

The Applecross grits above the north-western limb of the Sgiath-bheinn an Uird thrust do not always show any clear dip, but to the north-east of the line of section they dip to north-west at high angles. The same rocks above the eastern limb of the thrust generally dip to north-west, and are underlain by shales which may belong to the Kinloch division.

The section given in Fig. 64 is drawn along a south-easterly line about a mile to the south-west of the last. It shows the same anticlinal folding of the two thrust-planes as in Fig. 62. It differs from that section chiefly in showing above sea-level the western limb of the Sgiath-bheinn Tokavaig thrust-plane and the overlying rocks, and in extending further to the south-east so as to show the position of the Moine thrust with its Lewisian gneiss which may once have stretched westwards over all the other rocks in the section. The rocks indicated in the present section below the Sgiath-bheinn an Uird thrust are separated from those shown in the same position in Fig. 62 by the near.y

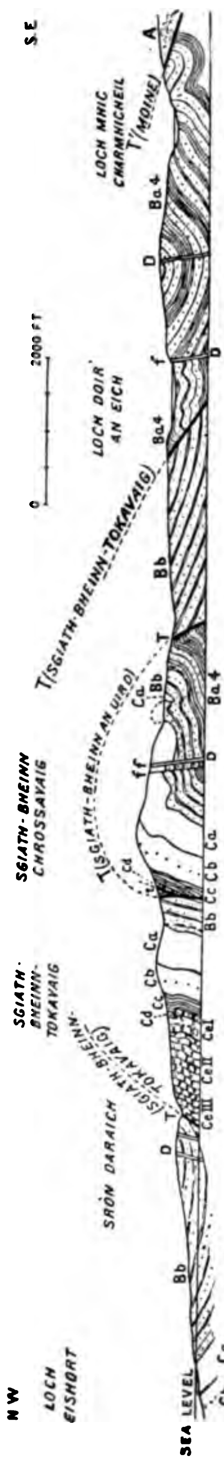

FIG. 64.—Section from Loch Eishort over the north side of Sgiath-bheinn-Tokavaig and the south side of Sgiath-bheinn Chrossavaig to Loch Mhic Charmhicheil.

A. Lewisian Gneiss. Ba⁴. Kinloch Beds (Torridonian). Bb. Applecross group. Ca. Basal Quartzite (Cambrian). Cb. Pipe-rock. Cc. Fucoid-beds. Cd. Serpulite Grit. Ce I. Ghrudaidh group. Ce II. Eilean Dubh group. Ce III. Sailmhor group. D. Tertiary Dykes. T. Thrusts. T'. Moine thrust. t. Minor thrust. f. Faults.

vertical crush which in the section in Fig. 63 divides the mass below the thrust into two nearly equal parts. The Torridon Sandstones are a continuation of the mass on the west side of the crush, and include beds belonging both to the Applecross (Bb) and the Kinloch divisions (Ba⁴).

The western limb of the Sgiath-bheinn an Uird thrust is sometimes reversed, with an inclination of 70° or 80° to E.S.E. The beds on the western side of this limb must have been pushed over those on the east side, for the outcrop of the thrust can be traced all round the south-west apex of the anticline. At this apex the crushed surface of quartzite which marks the thrust-plane is generally inclined southward at angles between 26° and 30°, while two or three hundred yards further north-east similar crushed surfaces along the south-eastern limb of the thrust dip towards south-east at 60° or 70°. The portion of this limb which has Torridon rocks on either side of it is not so easily traced as the other, for the Applecross grits (Bb) which overlie the thrust include some shale-bands like those in the Kinloch division below (Ba⁴).

The north-western limb of the Sgiath-bheinn Tokavaig thrust is well exposed in a little burn a third of a mile E.S.E. from Sron Daraich, where it is inclined at 50° in a direction slightly north of west. About 1000 yards south of Sron Daraich the inclination is 65° in an E. S. E. direction. At, and near, the top of the wood half a mile S.S.E. from Sron Daraich a siliceous breccia, at least ten feet thick, appears along the Sgiath-bheinn Tokavaig thrust, and covers several acres. Its matrix is hard, fine-grained, and contains drusy cavities. The fragments enclosed in the matrix are all angular, and in some exposures are nearly all of a cherty rock, in general finely-banded, and buff or pale-red in colour. Some are opalescent or dark-brown or almost black. The cherty pieces are often packed tightly together, and among them are cracked masses of banded chert, some of which are a yard long. Where the breccia overlies the quartzite and is seen lying along the thrust-plane the colour of the matrix is pale-grey, and the included pieces are then chiefly of quartzite. This breccia has obviously been produced by friction along the thrust. It includes, however, no pieces of Torridonian rocks, though a mass of such rocks occurs on the west side of the thrust, and no doubt once overlay the breccia. Included pieces of limestone are also absent, and the matrix is never calcareous, though it contains many pieces of cherty rock that might be supposed to have been derived from beds of limestone. The limestone which underlies a portion of the breccia belongs partly to the Ghrudaidh zone (in which there is very little chert), partly to the lower part of the Eilean Dubh division, in which chert is abundant, though rarely occurring there in such thick pieces as some of those in the breccia. The cherty rock might be supposed to have been dragged along from distant limestone areas now buried under the thrust, but this supposition would still leave unexplained the absence of limestone fragments. Perhaps the cherty rock may belong to some vein-stuff formed along the thrust and then broken up by renewed movement.

The south-eastern limb of the Sgiath-bheinn Tokavaig thrust-plane is tolerably distinct on the west side of Loch Doir' an Eich, where at one place near the north end of the loch a crushed surface of Applecross grit just below the plane dips E.S.E. at about 40°, and the colour of the rocks has been changed from red to grey. The beds exposed along the section in Fig. 64 above the west limb of this thrust consist of Applecross grits and basal quartzite, but in an inverted position. The quartzite can be traced along the coast from Ord Bay to Dun Scaich, a distance of nearly a mile and a half, always dipping below the grit, sometimes at as low an angle as 28°. The strata continue in this relative position far south of the line of section. When the quartzite comes near the Sgiath-bheinn Tokavaig thrust on the south side of Ord Bay it bends and assumes a south-easterly strike, but still dips below the Applecross grits. The outcrops of many of the more prominent bands of grit in the inverted upper portion of the Kinloch sub-division have been mapped, and they also are found to take a similar south-easterly strike as they approach the thrust. All the strata, therefore, between the quartzite and these Kinloch grits form parts of a syncline, in which their normal position is inverted. They not improbably once formed

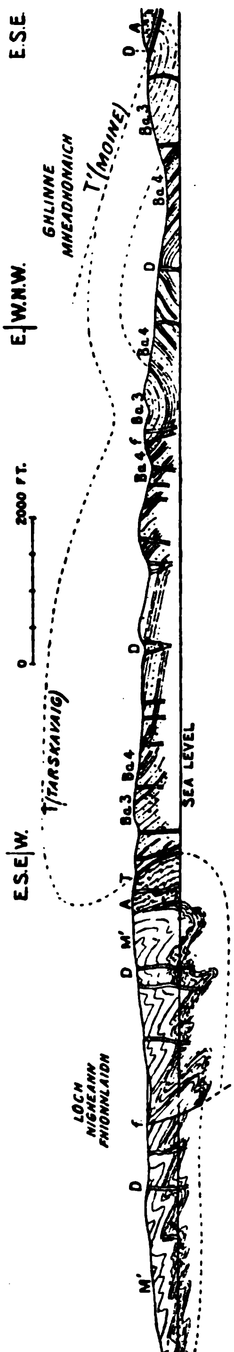

FIG. 65.—Section from Loch Eishort across Loch Nigheann Fhionnlaidh and the head of Ghlinne Mheadhonaich.
A. Lewisian Gneiss. Ba^3. Beinn na Seamraig grits (Torridonian). Ba^4. Kinloch Beds. M'. Tarskavaig Moine Schists. D. Tertiary Intrusions. T. Thrusts. T'. Moine thrust. f. Faults.

the under limb of a great isocline with both limbs dipping towards south-east. When the Sgiath-bheinn Tokavaig thrust was arched into an anticline the under limb of this supposed isocline may have been folded and inclined towards south-west near the thrust. That the strata beyond the western limb of the thrust had already been inverted before Mesozoic time is proved by the occurrence of an outlier of the basal conglomerate of the Mesozoic series resting on the reversed beds near Tarskavaig. But these reversed beds may not have already received the tilt which caused them to dip towards south-west near the thrust. It is, therefore, not impossible that the fold which affects this thrust may be of Mesozoic or even later age.

The rocks above the south-eastern limb of the Sgiath-bheinn Tokavaig thrust consist of shales and grits like those of the Kinloch division, but they vary a good deal in strike and dip, and contain no bands which can be traced so as to show the physical structure of the ground. The intrusions shown in the section are all basaltic dykes which have directions not much different from that of the section itself. The oncoming of the Moine thrust-plane with its overlying gneisses is shown at the eastern end of the section above the hollow of Loch Mhic Charmhicheil.

In the next section (Fig. 65), drawn along a line about four miles to the south-west of that shown in Fig. 64, a different series of rocks is represented, together with another type of tectonic arrangement. The most striking feature in this line of traverse is the appearance of another major thrust which has carried forward a series of rocks unlike any that lie to the north of them. Above this important line of dislocation, which has been named the Tarskavaig thrust, lies a series of sheared rocks undoubtedly belonging to the Lewisian gneiss; likewise a mass of altered sediments—the Tarskavaig-Moine schists (M')—in a much more altered condition than the adjacent Torridonian materials. These schists represent what were originally false-bedded grits and sandy and gritty shales. They must have had some resemblance to the Diabaig sub-division of the Torridonian series, but they do not exactly match any members of that sub-division yet found in Skye or elsewhere. No conglomerates lie between them and the gneiss such as usually occur at the base of the Diabaig series. If they represent an altered Torridonian formation they must have been pushed from an area in which the conditions of deposition somewhat differed from those indicated by the known Torridonian groups elsewhere, and in which also the rocks were more altered than further to the north-west. The Tarskavaig-Moine schists are less altered than the Moine-schists on the east side of the Moine thrust, but in their relations to the Lewisian gneiss these two sets of schists closely resemble one another. Originally they probably had much the same lithological characters and stratigraphical sequence, the altered shales occurring chiefly near the gneiss rocks and the more siliceous rocks further away.

The mass of gneiss and schist on the Tarskavaig thrust was once pushed over the southerly continuation of the Torridonian and Cambrian rocks in Fig. 64, but it has been folded into a syncline with an axis striking N.N.E. and with its eastern limb often inverted, so that it sometimes dips below the Torridonian rocks. This axis is nearly parallel to, but about a mile west of, that of the anticline of the Sgiath-bheinn an Uird and Sgiath-bheinn Tokavaig thrusts, and is a continuation of the axis of the syncline of inverted strata between the western limb of the last-named thrust and the shore.

The line of section now to be considered crosses a considerable part of the Torridon area in a nearly easterly direction, almost parallel to the local strike and the south end of the folded Sgiath-bheinn Tokavaig thrust. The strata exposed belong partly to the Beinn na Seamraig grits (Ba^3) and partly to the shaly Kinloch division. The Beinn na Seamraig grits form three separate patches which, a little south of the section, near the burn in Ghlinne Mheadhonnaich, unite and form parts of one exposure which extends south-eastward to the Moine thrust. In the middle and eastern patches, and in the parts which occur between them further south, the Beinn na Seamraig grits are inverted so as to lie above the Kinloch beds, but in the western patch they dip below these beds as if in their original order. This latter patch, however, lies close to the eastern limb of the Tarskavaig thrust—a limb which, though inclined in the same direction as it probably was originally, has yet been bent completely over, so that the Torridon beds which lay under now lie over the thrust. The eastern boundary of the west patch of grit may possibly have been bent over at the same time with the thrust at the western boundary, and perhaps before the eastern limb of the Tarskavaig thrust was reversed the beds in the west grit-patch were already in an inverted position, like those in the middle and eastern patches. It may be allowable to suppose that near the line of section the Torridon beds were first folded into a great isocline with its axial plane striking towards N.N.E. and hading towards E.S.E., and that the Beinn na Seamraig grits and Kinloch beds now exposed formed part of the reversed limb of this isocline. A subsequent plication may have folded the axial plane and also the Tarskavaig thrust.

No cleavage has been detected in any of the Torridon beds in this section, but the surfaces of the shales have often a glazed appearance like that often to be seen in Carboniferous shales in the neighbourhood of faults. At various places along the portion of the Tarskavaig thrust which outcrops north of the line of section thin bands of streaky crush-rock appear, which have perhaps been made out of the underlying Kinloch beds. In the north-east bank of Gillean Burn, nearly three-quarters of a mile west of Loch Dhugaill, a dark-grey shaly rock contains oval bits of grit, from the size of a pea to that of a duck's egg, which are swathed round by the streaky laminæ of the matrix.

The Tarkavaig thrust-plane, where exposed both at the north end of the syncline and also in many places in the western limb, overlies Kinloch beds and is there inclined at gentle angles. The eastern limb is not often visible. Near the south side of Gillean Burn it is nearly vertical, and further east is often reversed. A quarter of a mile south of the place where it is cut by the line of section it inclines to the east at about 55°.

The rock-mass whence the materials that overlie this thrust were driven seems to have most readily broken either within, or just at the top of, the Lewisian gneiss. In nearly all the best sections of the thrust-plane some of the gneiss rock, even if only a few inches, may be seen still lying upon it. When the thrust took place the gneiss was probably already in a soft granulitic and sheared condition, much as it is now, and formed part of a belt of weakness along which the displacement proceeded. That both the gneiss and the schists had been granulitised before the thrust took place may be inferred from the numerous small folds which are seen in them, and which do not fold the thrust. Many of these folds are isoclinal, and are crossed by foliation-planes parallel to the axial-planes. Near the north-west end of the section this foliation dips towards east or south-east at from 30° to 50°, and the thrust is inclined towards the south-east, probably nearly as it was originally, so that the dip of the axial planes of fold in the rocks above the thrust may also be nearly the same as it was originally. If this supposition be correct, the force which produced these folds must have proceeded from above from a south-easterly direction—the same direction as the force which subsequently thrust the schists forward and afterwards folded the thrust-plane.

In the eastern limb of the syncline the width of the gneiss outcrop is generally considerably more than in the western, but the gneiss rocks often cannot be easily separated from the altered sediments, both having been intensely sheared along parallel planes, and perhaps also mixed in thin stripes in places. The phyllite near Loch Nighean Fhionnlaidh occurs on the downthrow side of a large north-easterly fault, which hades towards south-east, and on the north side of Gillean Burn throws down the Tarskavaig thrust-plane in an easterly direction, displacing its outcrop about 300 yards.

The differences between the Tarskavaig-Moine schists and the Moine-schist east of the Moine thrust indicate that the latter have been more highly metamorphosed than the former. The Moine thrust overlies the Tarskavaig thrust, and the rocks brought forward on it have doubtless been driven for a greater distance from the south-east than those displaced by the latter thrust. It is the schists which once lay furthest to the south-east that are in the most altered condition. We may suppose that before the thrust movements began the rocks now overlying the Tarskavaig and Moine thrusts formed parts of one rock mass composed partly of Lewisian gneiss rocks and partly of altered shales and grits, and that the metamorphism of this mass increased in intensity in a south-easterly direction.

The Moine thrust is not clearly exposed near the line of section. Half a mile further south a basalt sill, about five feet thick, which has been injected along the thrust, dips to the south-east at 15°, and the inclination of the thrust is probably about the same.

The last section (Fig. 66) of this series across the peninsula of Sleat has been drawn along a line still further to the south-west. It presents a much larger area of Lewisian gneiss (A), and of the schists of sedimentary origin associated with them (M′), than that shown in Fig. 65. These schists have here been carried forward over almost unaltered Torridonian rocks by three thrusts—the Tarskavaig thrust, the outcrop of which is not seen in the section; the Caradal thrust, lying above the Tarskavaig thrust; and the Loch Lamarscaig thrust, which lies partly on the Caradal and partly on the Tarskavaig thrust. These three thrusts have been folded into synclines with axial planes striking towards the north-east. The axis of the Loch Lamarscaig thrust runs some distance to the south-east of those of the others, and this thrust has perhaps been folded after the others, which may possibly have received their plication when the mass on the Loch Lamarscaig thrust was being driven over them, while that thrust in its turn may have been folded before the mass that was advancing on the Moine thrust.

In several places along the Caradal thrust, and in one place along the Loch Lamarscaig thrust, patches have been observed of the Torridonian epidotic grits and conglomerates having phyllites, granulitic schists, or sheared gneiss on both sides. A certain amount of crushing has affected the adjoining Tarskavaig-Moine schists as well as the epidotic beds, and has helped

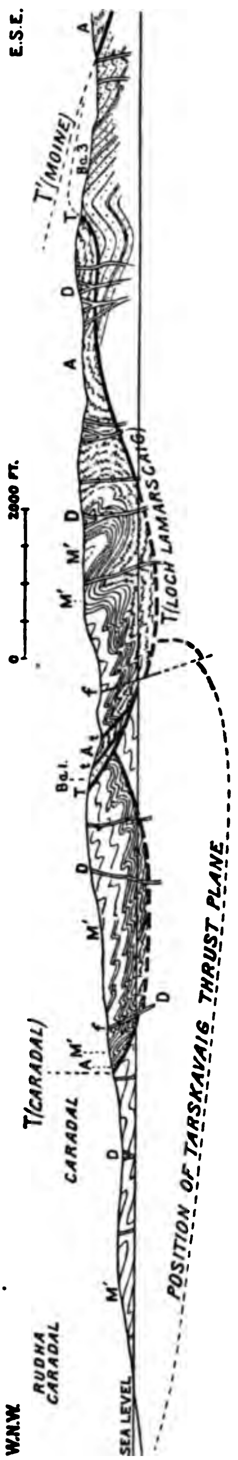

FIG. 66.—Section from the coast at Rudha Caradal past the north side of Loch Lamarscaig to the west side of Calligarry.

A. Lewisian Gneiss. Ba¹. Epidotic Grits (Torridonian). Ba³. Beinn na Seamraig Grits. M'. Tarskavaig Moine Schists.
D. Tertiary Dykes. T. Thrusts. T'. Moine thrust. t. Minor Thrusts. f. Faults.

to obscure the earlier differences between these two sets of rocks. In a specimen (7649) of granulitic schist collected near a patch of the epidotic conglomerate, the granulitic laminæ are repeatedly crushed along lines which cross the foliation. Excepting along some special thrust-like lines the epidotic beds are not granulitic, the outlines of the larger pebbles being generally distinct and showing no parallel elongation. Mixed with the epidotic grits, in an area half a mile to the south-west of Loch Lamarscaig outlet, dark-grey gritty shales and purple and green sandy shales may be seen. None of these shales are lustrous, and in this respect they contrast greatly with the adjoining Tarskavaig-Moine phyllites.

Just under the Loch Lamarscaig thrust the Beinn na Seamraig grits and shales are a good deal crushed, but not otherwise appreciably altered. They only cover a small area between the eastern part of that thrust and the Moine thrust, and are not clearly exposed. Further south their width becomes still narrower, and about a mile and a quarter north-west from Tormore the Moine thrust rests directly upon the gneiss on the Loch Lamarscaig thrust. The materials that overlie the Tarskavaig thrust are only exposed at the north-west end of the section, and consist of granulitic schistose grits, with a few subordinate beds of sandy phyllite which are not shown in the section: the foliation planes generally dip to south-east at between 28° and 50°, but near the Caradal thrust they are sometimes nearly flat, or strike to north-west. The phyllites and gneiss rocks which come below the schist on the west limb of the Tarskavaig thrust in Fig. 65 are probably hidden under the sea in this section.

The outcrop of the Tarskavaig thrust is overridden by the

Loch Lamarscaig thrust at a place about half a mile south of the outlet of Loch a' Ghlinne, where the latter thrust is gently inclined towards south-east. The Tarskavaig thrust is not there distinct, but from the north side of Loch a' Ghlinne to within 200 yards of the Loch Lamarscaig thrust it strikes nearly north and south and is steeply inclined. Nearly a third of a mile south-east of the line of section the inclination of the western limb of the Caradal thrust is 29° to south-east, and a quarter of a mile further north-east it is 30° to south-east. The outcrop of this thrust is overridden by the Loch Lamarscaig thrust nearly half a mile slightly west of south of the Loch a' Ghlinne outlet, and the inclination here is gently westward.

Above the western limb of the Caradal thrust in a few places thin stripes of rock have been noticed which may be regarded as sheared forms of Lewisian gneiss, but they cannot always be confidently separated from the overlying sandy phyllites. The patch of gneiss shown in the section is not more than 200 yards long, and no other gneiss can be seen for more than a mile to the south-west. The sandy phyllite above the sheared gneiss is about 100 yards broad and generally dips to south-east. About 100 yards east of the top of this phyllite another much thinner band of phyllite of similar material is succeeded by overlying granulitic schists which are generally somewhat pebbly and more massive than those below.

On the east side of the epidotic beds shown in the section, and probably separated from them by an obscure thrust, a flaggy pale-grey mylonised gneiss makes its appearance, the parallel planes of which are much crumpled but generally dip east or south-east. This gneiss may be separated by a minor thrust from the much broader exposure shown above the eastern portion of the Loch Lamarscaig thrust. The rock in this exposure is to a large extent composed of thin pale-green and red streaks, the former probably representing sheared basic laminæ, and containing occasional round fragments and lenticles of hornblende and hornblende schist, while the red streaks represent the more felspathic laminæ in the gneiss, or perhaps in some cases veins of pegmatite which have been sheared with the gneiss. Close to the Loch Lamarscaig thrust the planes of the sheared gneiss are in places so much broken that the rock loses its flaggy character.

The rocks between the two exposures of sheared gneiss above the Loch Lamarscaig thrust consist of sandy phyllites and siliceous granulitic schists. Next to the gneiss on the east part of the thrust lies a thin band of granulitic schist, followed by a thick phyllite which is perhaps part of the band seen next to the gneiss in a good many other places on the Caradal and Tarskavaig thrusts. The Moine thrust is not distinct at the south-east end of the section, but in two places in Allt a' Chamaird some rocks in the thrust are exposed, and include a sheet of basalt and a band of mylonised rock, ten feet thick, which contains eye-shaped pieces swathed round by thin streaks resembling crushed shale. The mylonitic streaks generally dip to south-east at about 20°, and are probably parallel to the thrust.

PART V.

THE EASTERN SCHISTS.

CHAPTER XL.

GENERAL DESCRIPTION.*

Under the name of "Eastern Schists" is here included the great series of crystalline schistose rocks which lie upon the uppermost of the major thrust-planes of Sutherland and Ross, and stretch eastwards into the rest of the Highlands. These rocks have been the subject of much discussion. They were once regarded as portions of the oldest or Azoic architecture of the country. Murchison considered them to be a metamorphic series of mainly sedimentary formations, later in date than the Lower Silurian (Cambrian) limestones and quartz-rocks which underlie them, and into which they seemed to pass downward in a conformable succession. The detailed study of them by the Geological Survey has thrown considerable light on their composition and structure, but the problem of their age and origin has not yet been completely solved. In this and the following chapters nothing more will be attempted than a general account of their characters as these have been ascertained along the belt of country examined between the north coast of Sutherland and the Point of Sleat in Skye. When the rest of the Highlands lying to the east of that belt has been surveyed, it may be possible to offer some more definite opinion as to the stratigraphical relations and history of these rocks.

The "Eastern Schists" have had various names applied to them. Most of these appellations have had reference to the petrographical characters of the rocks, such as "gneissose flagstones," "quartzose schists," "flaggy schists." Sometimes the designation selected has expressed their supposed stratigraphical position, such as "younger gneiss" or "upper gneiss." The members of the Geological Survey when they began to map them in the north of Sutherland and found them spreading over the wide tract known as The Moine in that county, distinguished

* By J. Horne and J. J. H. Teall.

them as the "Moine schists." As no one petrographical term will adequately describe them, and as their stratigraphical relations are somewhat complex and obscure, it has seemed best to class them in the meantime under some geographical name which will involve no theoretical implications. Accordingly they may be conveniently described as the "Eastern Schists" or "Moine Schists."

The detailed descriptions and illustrative sections given in Chapters XXXII. to XXXIX. of this Memoir have shown that, throughout the long belt of complicated structure in the North-West Highlands, however much that structure may vary in tectonic arrangement from district to district, every section taken across its breadth invariably terminates eastwards in the oncoming of the Eastern schists above the Moine thrust-plane or most easterly of the great displacements. If the actual plane of this thrust could always be seen it might be taken as the western limit of these schists. As already mentioned, it has been clearly exposed in some places, such as the precipitous sea-cliff east of Loch Eireboll, the Stack of Glencoul, near Knockan in Assynt, and between Stromeferry and Loch Alsh. But it is often extremely difficult to determine the precise position of this thrust-plane. Owing to the development of mylonised rocks about its horizon, the actual "sole" or plane of displacement is apt to be lost among the crushed and rolled-out materials which have been driven along in the line of movement.

Near Tarskavaig in Sleat, Skye, a considerable body of schistose rocks, resembling in some respects the Moine schists, has been brought forward in advance by displacements below the horizon of the Moine thrust. These rocks, which have been termed the Tarskavaig Moine schists (Chapter XLII.), comprise phyllites, sometimes interleaved with siliceous schists and gritty beds, which, in one locality, present a spotted appearance, due to the presence of minute aggregations of black mica or chlorite evidently of secondary origin. It is suggested that the micaceous spots may have resulted from contact metamorphism near some igneous intrusion, and though probably earlier than the thrusting movements, must have been later than the regional metamorphism. Overlying the phyllites come schistose grits with pebbles of quartz and microcline-felspar, the quartz grains being elongated and in part granulitised.

Again, on the mainland, in the Cnoc Daimh Burn in the Coulin deer forest, Kinlochewe, close to the Moine-schists, though the junction is concealed by alluvium, certain fine-grained platy rocks and siliceous schists are to be seen presenting petrographical types intermediate between normal sediments and crystalline schists, which may not improbably belong to the basal division of the Torridonian system, though this correlation cannot be demonstrated. (Chapter XXXVII.)

The materials which supervene above the Moine thrust may be grouped in four main divisions:—(1) Mylonised rocks; (2) phyllitic schists, siliceous schists, and limestones, especially characteristic of the Durness-Eireboll district (crushed rocks and frilled schists of the one-inch map, Sheet 114); (3) granulitic quartzo-felspathic schists, frequently referred to as Moine-schists, with which are associated thin bands of garnetiferous mica-schist; and (4) inliers of micaceous and hornblendic gneiss recalling, in certain areas, types of Lewisian rocks to the west.

(1) A remarkable feature of the Moine displacement is the belt of mylonised rocks found either above or in association with that plane. In some places this belt measures a mile or more across, elsewhere it may be only a few hundred yards, while sometimes it appears to be absent, the granulitic crystalline schists then lying immediately upon the plane or sole. In the field and under the microscope it can be shown that mylonites of variable tints—grey, green, pink, and striped—have been derived in part from different members of the Lewisian gneiss. All the stages in the process of deformation are to be found, the dark hornblende gneisses have been rolled-out into green platy schists, the pink pegmatites exhibit flow-structure like that of rhyolites, and the acid gneiss with pink quartzo-felspathic veins merge into the striped or banded mylonites. But in certain cases also it is apparent that the materials of this crush-zone are of sedimentary origin, for in Eireboll, in the Glencoul district, and in Assynt bands of basal Cambrian quartzite have been rolled-out into platy homogeneous quartzites in which the individual grains are hardly discernible with the unaided eye. Southwards in the Kinlochewe district it would appear that the epidotic grits and basal shales (Torridon) have also undergone mylonising processes in association with the Moine displacement.

The effects of crushing on the micro-structure of the rocks can be best studied in the acid gneisses, pegmatites, quartzites, and quartzo-felspathic grits. The original grains of quartz and felspar have been broken, and detached fragments now lie in a crypto- or micro-crystalline matrix which represents the ultimate results of the mechanical action. The plagioclase felspars illustrate the cataclastic effects in the greatest perfection on account of their twin lamellation. The first effect is seen in a simple faulting of the twin-lamellæ, and from this action to the breaking up of a large individual into innumerable fragments and the separation of the fragments in the matrix of fine-grained mylonitic material every stage may be followed. The same phenomena may be seen in quartz, especially in quartzites, but when quartz and felspar in juxtaposition have been simultaneously affected they behave somewhat differently. Quartz appears to yield without fracture to stresses tending to produce fluxion more readily than felspar, and what may be termed quartz-flow round angular grains or crystals of felspar may sometimes be observed. In such cases the appearance under the microscope suggests that an original grain of quartz of approximately equal dimensions in the different directions has been converted into a curved lenticle, and that in the process of deformation the crystalline individuality of the grain has been lost. In place of the original individual an aggregate has been produced, the constituents of which are also more or less lenticular in form.

In this connection it is worthy of note that two different types of schistose rocks have been produced in the north-west of Scotland by the deformation of solid rocks. In the pre-Torridonian shear-zones granular gneisses have frequently been converted into hornblende-granulites (see page 64) by shearing, without the development of cataclastic structures, or, in other words, by plastic deformation; whereas in the region of the post-Cambrian thrusts similar rocks have been converted into mylonites with marked evidence of the mechanical fracture of the original constituents. These two types no doubt correspond to differences of pressure and temperature at the time of deformation. The mylonitic type may be regarded as characteristic of the zone of fracture, and the granulitic type as characteristic of the zone of flow, but neither the two types nor the two zones are sharply separated from one another, for, as we have just seen, quartz may be in the zone of flow, while felspar is still in the zone of fracture.

(2) The phyllitic schists, siliceous schists, and limestones represent a sedimentary series which has been powerfully affected by the post-Cambrian movements. It is well developed in the Eireboll district, and may be studied also at Sangomore Bay and Fair-aird Head. The phyllitic schists often closely resemble phyllites, but under the microscope they are seen to have been highly crystalline before the final movements took place. The principal constituents are white mica, chlorite, and a micro-crystalline quartz-felspar aggregate. The rocks are usually dark-green in colour with wavy foliation planes, and the general appearance of a freshly-prepared hand specimen is not unlike that of a rock made up of broken oyster-shells; hence the term "oyster-shell rock" which has been frequently applied to these phyllitic schists. The movements which gave rise to this peculiar feature were posterior to the development of the plates of white mica which are seen under the microscope to have been bent and broken.

The siliceous schists are intimately associated with the phyllitic schists, sometimes as thin alternating laminæ and sometimes as thick bands which can be readily traced in the field. They are compact halleflinta-like rocks, with well-marked parallel structure, mainly composed of quartz, but containing also a few thin flakes of white mica. The micro-structure is of so fine a grain that the outlines of the constituents can only be made out in very thin sections and with a high magnifying power. The individuals of quartz are then seen to be irregular in form and greatly flattened in the planes of foliation. In other less typical varieties calcite is present, and this indicates a passage into the limestones with which they are also associated.

The limestones are well-banded crystalline rocks, composed of calcite with a few flakes of white mica and grains of quartz and felspar. The banding is well shown on a weathered surface in consequence of the projection of the more siliceous layers.

(3) The granulitic quartz-schists have the largest development in the belt between Eireboll and Sleat, and it was to these characteristic rocks that the name of "gneissose flagstones" was more particularly applied. They are usually flaggy, though sometimes massive, with muscovite and less frequently biotite along their divisional planes. Augen of quartz and felspar, which are of common occurrence, may represent the remnants of original clastic grains. Indeed, at one place, in the Rhidorroch Forest, six miles east of Ullapool, schistose pebbly grits are associated with the siliceous schists, the pebbles of quartz and felspar measuring a quarter of an inch across.

Important evidence regarding the relation of the post-Cambrian movements to the internal structure of the Eastern schists is furnished by the associated intrusive rocks. Thus, in the area south-east of Glendhu and Glencoul intrusions of foliated granite have their foliation-planes parallel to those in the adjoining siliceous schists. Again, at Leckmelm, near Ullapool, bands of foliated porphyrite resembling the type of oligoclase-hornblende-porphyrite in the thrust masses in Assynt (Chapters XXIX. and XXX.) are interleaved with platy mica-schists of Moine type. Similar evidence is obtained in the area east of Loch Ailsh and near the Knockan in Assynt, where sills of sheared porphyrite and syenite porphyry are intercalated among the Eastern schists, with which their foliation-planes coincide in angle and direction of dip. These metamorphosed sheets so closely resemble some of the intrusive sheets among the Cambrian rocks of Assynt, which were injected before the post-Cambrian movements (Chapter XXIX.), as to justify the inference that, whatever may have been the origin of the Moine schists, the dominant structures impressed on them and on the porphyrite sills must have been produced by the same movements. In addition to these acid intrusions, bands of basic material, composed of garnetiferous hornblende-schist and hornblende-biotite-schist, are associated with the granulitic schists of the Moine series, and display a similar parallelism of dip and strike.

Further evidence of the mechanical movement which all the Eastern schists have undergone is supplied by certain fine parallel lines on the divisional planes, alike of the platy mylonites, of the siliceous schists, and of the foliated granitic sills. The same striping or parallel lineation is sometimes seen in the sheared Torridonian strata that overlie the Kinlochewe thrust-plane. In all these positions the trend of the lines is usually W.N.W. and E.S.E., which has been shown to be the general direction of movement of the thrust masses.

Under the microscope the main mass of a typical Moine-schist, taken at some distance from the thrust-zone, is seen to be a micro-granulitic aggregate of quartz and alkali-felspar, in which flakes of mica are embedded. The grains of quartz and felspar are of approximately uniform size and shape, and the mica flakes do not merely lie between the constituents of the aggregate but are included in it, so that a single flake may pierce one or more contiguous grains. A rock of this character shows no traces of clastic or cataclastic structures; it is a holocrystalline schist.

But although these features are common in rocks which cover a very large area to the east of the Moine-thrust, they are not especially characteristic of the rocks immediately overlying the thrust. In these rocks cataclastic structures are not uncommon, and the question has arisen as to whether they represent crystalline schists more or less broken down or sedimentary rocks which are on the way, so to speak, to become Moine-schist. Both views have been held by different members of the Survey, and both views may be right, though not, of course, as applied to one and the same rock. The age and origin of the rocks that have been mapped as Moine-schists is a complicated problem which has not been finally and definitely solved, but abundant evidence has been accumulated to show that under the influence of the post-Cambrian movements rocks of diverse age and origin have acquired a common type of structure, and that true crystalline schists have been simulated if not actually produced.

(4) The inliers of gneiss, probably of Lewisian age, that are intercalated among the granulitic Eastern schists are specially prominent on the western slope of the ridge east of Loch Eireboll, between the Kyle of Tongue and the River Borgie in the north of Sutherland, and between Loch Carron and Loch Alsh in the south of Ross-shire.

The granular hornblende- and biotite-gneisses between Tongue and the River Borgie resemble the corresponding types in the undisturbed Lewisian gneiss of the western area; but certain granulitic gneisses—as, for example, those which occur to the south-west of the village of Tongue in the direction of Lochan Hacoin and Ribigill—are more closely allied to the rocks which occur in the pre-Torridonian shear-zones.

In the course of the survey of the Eireboll and Tongue area, it was inferred that the relations of the Moine-schists to the gneiss inliers were determined by the post-Cambrian movements, and that the original structures and stratigraphical connexions of the rocks had been more or less completely masked by these movements. More recent work, however, between Stromeferry and Loch Alsh has led Dr. Peach to the belief that the Moine-schists in that district rest unconformably on gneisses of Lewisian type. He has found what he regards as a conglomerate locally developed at the base of the Moine-schists and overlain by a definite order of succession among the schists analogous to that in the Diabaig group of the Torridon Sandstone. (Chapter XXXVIII.)

In connection with this view of the stratigraphical relations of the Eastern Schists, it should be mentioned here that, in the district between Stromeferry and Loch Alsh and also in Sleat, evidence has been obtained of the breaking down of the structures of the siliceous schists close to the Moine thrust-plane. It would thus appear that at least some of these rocks existed as crystalline schists before they had reached their present position. It may be further noted that a band of what is obviously a crush-conglomerate occurs in Balmacara Bay within the belt of Lewisian gneiss east of the great Moine displacement.

A striking characteristic of the Eastern schists is presented by the double system of folding which they possess. One system has a N.N.E. and S.S.W. strike, the inclination of the axial planes being E.S.E., thus harmonising with the strike and direction of dip of the Moine thrust-plane and of the divisional planes of the mylonised rocks in association with that displacement. This plication may be regarded as an obvious accompaniment of the movement of the thrust masses in a W.N.W. direction. The other system strikes generally W.N.W. and E.S.E. as if produced by forces acting at right angles to this trend. On looking at an escarpment of Moine-schists, the observer sees the ends of a series of folds, the axes of which run W.N.W. or north-west, lying along the inclined foliation-planes. Hence arises what might be termed "mullion" structure—that is, the production of a series of rods trending towards W.N.W. or north-west. This structure is admirably illustrated by the quartzite-rods of Beinn Thutaig (1340 feet) in the Moine-schist area east of the mouth of Loch Eireboll. (Chapter XLI.) It frequently happens that ridging-up has taken place along these axial lines, and that the divisional planes dip towards N.N.E. and S.S.W., the pitch of the folds being towards E.S.E. This second system of folding is to be regarded as one of the structures that have resulted from the post-Cambrian movements.

One final important feature in the stratigraphical relations of the Eastern schists remains to be noted. In the Durness district they are superimposed on the highest surviving sub-division of the Cambrian series; elsewhere they may be found resting on any formation among the displaced masses, including the thrust Lewisian gneiss, while in some places they have been driven completely across the belt of complicated ground, so as to lie on the undisturbed Cambrian strata further west.

CHAPTER XLI.

THE EASTERN SCHISTS FROM THE NORTH COAST OF SUTHERLAND SOUTHWARDS TO STRATH NA SHEALLAG.

I. LOCH EIREBOLL TO LOCH MORE.*

The best exposure of the Moine thrust-plane in the north of Sutherland is to be seen at the base of the Cleit an Seabhaig—a precipitous sea-cliff, about 600 feet high, nearly two miles east of the mouth of Loch Eireboll. Sheared gneiss and pegmatite form at that place the pavement or sole on which the displaced schists repose. Southwards the thrust-plane can be traced to the mouth of Loch Hope, and thence to the top of Creag na Faoilinn and Creag Earail, beyond which point to Loch More, though itself concealed, it gives rise to a conspicuous feature in the landscape.

At the base of the Eastern schists in Eireboll, green, platy, fissile mylonised rocks are followed by green, pink, and striped mylonites with alternations of gneiss, which, in places, has lost nearly all traces of its original structure. Immediately above the plane or in association with the lenticles of deformed Lewisian gneiss, wedges of rolled-out quartzite appear, which probably belong to the basal division of the Cambrian system. Next in order above the belt of mylonised rocks come frilled or corrugated mica-schist and phyllites (" oyster-shell rock ") with a thin band of limestone or calcareous zone near the top, visible on the Cleit an Seabhaig and along the ridge to the south-west of Loch Hope. Between Creag na Faoilinn and An Lean Charn the wavy phyllites alternate with bands of highly siliceous schist, the most prominent one being represented on Sheet 114, on the ridge to the south-east of the head of Loch Eireboll. Further to the east a lenticular belt of hornblendic and micaceous gneiss has been traced for a distance of eight miles from the west slope of Beinn Thutaig and across Loch Hope to Meall a' Bhaid

* By B. N. Peach and J. Horne, with notes supplied by H. M. Cadell. The district described in this chapter is represented in Sheets 92, 101, 102, 107, 108, and 114 of the Geological Survey Map of Scotland, on the scale of 1 inch to a mile ($\frac{1}{63360}$).

Tharsuinn. This gneiss is followed by a great development of granulitic siliceous schist with occasional bands of garnetiferous mica-schist. The granulitic quartz-schists have a wide distribution over the eastern slope of the A' Mhoine and southwards to Loch Hope.

All the successive bands of rock lying above the Moine displacement have been dragged into a general parallelism with that line of disruption, acquiring in consequence a strike to N.N.E. and a dip to E.S.E. But in the midst of the granulitic series frequent examples appear of folding along axes that trend W.N.W. and E.S.E. The most striking instance of this structure is to be seen on the south-east slope of Beinn Thutaig about three-quarters of a mile from the top of the hill. Here, as already alluded to, a series of rods, varying from two to four feet in length and from one to four inches in diameter, are composed of irregular grains of quartz with some flakes of white mica. These rods are associated with mica-schists of Moine type, which have there been thrown into sharp anticlines and synclines, with axes trending like the rods towards W. 12° N., and with a pitch towards the east. On exposed surfaces, where the mica-schist has been denuded into hollows, these siliceous ribs project and form conspicuous features in the landscape.

The same order of succession in the rocks above the Moine thrust-plane is observable in the Durness area on Fair-aird Head, and in a less complete form in Sangomore Bay. The platy mylonites, the rolled-out lenticles of quartzite, the frilled schist with the calcareous zone at the top, the reconstructed zoisite-gneiss, followed by the granulitic quartz-schists, are exposed partly at the one place and partly at the other. It is worthy of note that the fault-breccia along one of the normal dislocations north of Durine village, which have disconnected the Eastern schists at Durness from those at Eireboll, contains numerous fragments of these granulitic schists.

In the midst of the granulitic schists between the Kyle of Tongue and the River Borgie two inliers of gneiss contain types characteristic of the Lewisian rocks to the west. The more westerly, which has been traced from the village of Tongue southwards to Loch an Dithreibh, is bounded by siliceous schist, save on the north-west margin north of Lochan Hacoin, where it is in contact with platy hornblende-schist. The rocks consist mainly of grey banded biotite gneiss with pegmatites, whose strike roughly coincides with that of the adjacent schists of sedimentary origin. But in some places—as, for instance, near Ribigill Farm—masses of coarse-grained hornblende-gneiss appear which closely resemble a type in the Cape Wrath area.

A still larger belt to the west of the Borgie River is about two miles wide, and extends southwards from the north coast for a distance of seven miles to Loch Creagach. It consists mainly of hornblendic gneiss with masses of rudely-foliated diorite and dykes of ultra-basic materials, which present some of the features of the Lewisian masses to the west. These rocks are bounded by flaggy quartz-biotite schists or gneisses, which have been included with the Moine series. Bands of hornblende-schist are interleaved in that series between Strathan and the village of Tongue, but the most persistent zone of this type is that which has been traced from the head of the Kyle of Tongue round the northern and western slopes of Ben Hope. (Sheet 114.)

The order of succession of the rocks above the Moine thrust-plane which obtains in the Eireboll and Durness district has not been traced further south than Creag Earail beyond the head of Loch Eireboll. Southwards to Loch More the plane is well defined, its average angle of inclination being about 6°, though in some places it is higher, while at Loch Vuckernich, about a mile north of Loch More, the plane becomes horizontal. Immediately above the plane of disruption a belt of green schist with felspar "eyes," intensely crumpled and contorted, has been produced, partly from the deformation of Lewisian gneiss and partly from sedimentary materials. Overlying this belt come the granulitic quartzose schists with partings of mica-schist.

II. THE EASTERN SCHISTS FROM LOCH MORE TO LOCH GLENCOUL.*

Between Loch More and Gorm Loch Mor the Eastern schists comprise the zone of (1) mylonised rocks at the base, followed by (2) a group of "puckered" ("Stack") schists—extremely fine-grained much-puckered rocks, containing many streaks and thin bands of greenish-grey quartzose schist or slate—and then by (3) granulitic siliceous flagstones with thin micaceous schists.

South of Loch More the schists in some places lose their usual N.N.E.-S.S.W. strike and E.S.E. dip, and become approximately parallel to the adjacent portion of their curving western boundary. Between Loch na Creige Duibhe and Beinn Lice, for instance, they generally dip to north-east or E.N.E., while between Loch Strath nan Asinnteach and Meall na Leitreach they dip to south-east, and in the southern slopes of Gleann Dubh almost to due south. These different directions characterise different sides of a great fold into which the Eastern schists have once been thrown. The highest parts of the folded area have now been denuded away, but the lower parts on the north-east and south remain. The fold has not affected the Glencoul thrust, and has perhaps been formed while the higher thrusts were in progress.

(1) In this district, as in that of Eireboll and elsewhere, a belt of mylonised rock usually divides the other Eastern schists from the rocks which lie further to the west. Except on the hill between Loch More and Loch na Creige Duibhe—where its breadth is about a mile—it is never here as much as a quarter of a mile wide. Near Beinn Lice, Glen Coul, and Loch an Urchoil it seems generally to be only 10 or 20 feet thick, and in some places it perhaps does not exist. In one section near the head of

* By C. T. Clough.

Loch Strath nan Asinnteach it is certainly not present. Besides this most western outcrop, other bands of mylonised rock appear above or between portions of the "Stack" schist at the head of Loch Strath nan Asinnteach, rather more than one and a half miles south-east of Glendhu (house), near the head of Glen Coul, and at various other places.

About a mile and a half south-east of Glendhu a mylonised rock passes gradually into Lewisian rocks, which have been only partially mylonised, and which are overlain unconformably by the Cambrian quartzite. On the hillside between Loch More and Loch na Creige Duibhe a gradual transition appears to be traceable between a mylonised rock and the granulitic flagstones. But, nevertheless, the mylonised belt is in most places fairly well defined or separated by thrust-planes from the other rocks.

(2) The Puckered or "Stack" schists consist chiefly of rather dark-grey laminæ mixed with others that are paler and more quartzose. Their material is throughout extremely fine-grained, and often appears as if its different parts had been kneaded together, individual laminæ being not only intensely contorted, usually along axial planes which dip east, E.S.E., or north-east, but also crossed by little thrust-like lines which hade in the same direction as the axial planes. For instance, in the section on the north-east side of Loch Strath nan Asinnteach, about 250 yards from the head of the loch, some of the broader laminæ are themselves divisible into minor laminæ, partly of a very quartzose character, which are inclined at a considerable angle to the upper and lower surfaces of the broad laminæ of which they form a part. It looks as if, perhaps, the rock had been piled up by a series of small thrusts, as some of the large rock-masses below the Glencoul thrust have been.

The quartzose streaks in the schist are very numerous, but none of them, as a rule, is more than an inch or two thick. A specimen from one of the thickest bands, about 30 feet above the base of the group in the Stack of Glencoul, has been sliced, and examination shows it to be a sericite schist or slate. (Specimen No. 3865.)

The Stack schists are well seen on the north-east side of Loch Strath nan Asinnteach, where they overlie the quartzite. At the loch their outcrop has a width of perhaps about 20 yards, but further south it is generally much broader. At one place, about 1500 yards south-west from the outlet of the loch, these schists are, perhaps, not represented at all. Near Lochain Feith an Leothaid and the head of Glen Coul the breadth of the band averages about half a mile.

Near Loch Strath nan Asinnteach it is difficult to draw a sharp line between these schists and the Cambrian quartzite, but, on the other hand, near Lochain Feith an Leothaid and between that tarn and Glen Coul, they appear to pass gradually upwards into the granulitic flagstone series, the change taking place in a width of 30 or 40 yards.

Ungranulitised pegmatites, rarely more than about an inch broad and running usually along the foliation planes, are rather common in this group. In some places, as on the north-west side of Loch nan Caorach, about a quarter of a mile E.N.E. of the outlet, these pegmatites are disposed in sharp isoclinal folds, and appear to have been folded together with the rest of the rock.

Various planes, resembling thrust-planes, and nearly parallel to the adjacent thrusts in the Cambrian rocks, have been observed within the Stack schists. The most conspicuous of these planes crosses the hill between Loch Feith an Leothaid and Glen Coul, keeping near to, but slightly below, the line taken as the boundary between the Stack schists and the granulitic flagstones. A brecciated rock is excellently exposed along the plane over a large area on the south side of the lochan about three-quarters of a mile N.N.E. from Loch an Urchoil. It inclines to east or slightly south of east, usually at angles varying between 14° and 17°, and from the character of the schist fragments it contains, it is clear that at the time of its formation the neighbouring rocks must have had essentially the same characters as they now possess. Another similar plane of brecciation is seen about a mile north from Loch an Urchoil, and probably lies a little below the plane just described.

(3) The Granulitic Siliceous Schist series covers a much larger proportion of the area at present mapped than either of the other groups. Its western portion includes the hills of Beinn Lice (1485 feet), Meall na Leitreach (1852 feet), and Beinn Leoid (2597 feet), but it is much less diversified by steep valleys and fresh-water lochs than the Lewisian gneiss areas lying further to the west, and it is covered also in many places with great expanses of morainic drift.

These extensively-developed schists present a remarkably uniform petrographical character. In none of them have any grains been observed which could be confidently taken to be of clastic origin. Occasional scattered grains, usually about the size of small peas, of white ungranulitised felspar may be noticed, but these are possibly of secondary origin. They are seen in various parts of Meall Leitreach, and with special clearness about a quarter of a mile north-east from the Ordnance station. Besides these grains, others consist of felspar and quartz mixed. About 1500 yards E.N.E. from Beinn Leoid some of these compound spots are as much as half an inch in length, and are scattered irregularly through the different rock bands.

On the foliation-planes of these schists a faint lineation or stretching may often be noticed. It seems usually marked by the arrangement of the quartz-granules and mica-flakes in directions towards W.N.W., N.W., or N.N.W., more or less at right angles to the general foliation-strike of the district.

The more micaceous schists intercalated among the granulitic schists generally contain many small garnets, and are characterised by a certain irregularity in their foliation, probably due to gentle puckering and occasional intersection by lines of strain-slip. In other places they have been thrown into a series of sharp little folds which do not show themselves in the adjacent quartzose schists. The mica-flakes—chiefly of a white, but partly of a black or brown, colour—vary in size in different districts, but can everywhere be distinguished fairly well by the unaided eye. Some of the bands effervesce with dilute hydrochloric acid, but no calcite streaks appear sufficiently large to be discerned in hand specimens.

Few of these more micaceous intercalations are sufficiently thick to be traced far. Perhaps the thickest band noticed in this district is about 30 feet thick. It occurs about half a mile slightly east of south of Beinn Lice, and seems to run in a N.N.E. direction for about half a mile. Certain portions of it effervesce with dilute hydrochloric acid. It is also mixed with thin bands of more siliceous character.

Many thin pegmatites are observable in this series of schists, most of them approximately parallel to the foliation. They rarely exceed an inch or two in thickness. We do not remember to have noticed granulitisation in any of them, either in the quartz or the felspar. Some thin quartz-veins, however, which appear a mile and a half N.N.W. and half a mile slightly west of north of Beinn Leoid, run parallel to the foliation, and are somewhat schistose parallel to their sides

The granulitic schist series between Loch Strath nan Asinnteach and Gorm Loch Mor includes a set of intrusions which show great variety both in chemical composition and structure. Some of them are granitic, while others are chiefly composed of hornblende and black mica. Different parts of one mass often differ greatly in the proportions of the pale and dark constituents, and occasionally—as, for instance, on the north side of Loch nam Breac Mora, and about a third of a mile N.N.E. of the foot of Loch an Urchoil—dark hornblendic rocks are closely associated with others of granitic type as if possibly both were parts of one intrusion. In large exposures of these rocks indications of foliation are always observable, but the degree in which this structure has been developed greatly varies in different parts. The rocks also display great variety in their modes of occurrence, some of them occurring as sills, others as short irregular dykes, and others small bosses, but none of them are fine-grained at their margins. As a general rule the granitic intrusions form the bosses and dykes, while the basic rocks have a greater tendency to take the shape of sills. No evidence has been obtained to show that the intrusions are of different ages.

In various places—as, for instance, at the east end of the granitic mass a mile slightly west of south of the foot of Loch Strath nan Asinnteach, and at the sides of dykes near Loch Dubh—the different bands of the granulitic schist series are distinctly cut by the edges of the granitic intrusions. It seems certain that the rock into which the granite was intruded must at the time of the intrusion have been composed of bands having much the same chemical composition as those we now see.

It is quite possible, however, that the material in the different bands may have been recrystallised during, or subsequently to, the time of the intrusions. The quartz in the granitic rocks, even those which show but little foliation, appears to be always in a granulitic condition, and it may have acquired this character while the siliceous schists were being granulitised. The felspar grains in the granites have frequently also a clear zone of recrystallised material around their margins (Specimen No. 2948, from 300 yards south of Loch Dubh, and No. 2949, from about a third of a mile north of the foot of Loch an Urchoil), or they "tail off" into thin granulitic streaks. Further, the foliation-planes in some of the more perfectly foliated granitic gneisses are parallel to those in the neighbouring siliceous schists, and they display "stretching" lines in about the same direction.

The question of what has led to the recrystallisation of the schists and of the intrusions in them is not easily answered. The quartz and felspar of the thin pegmatites which occur so abundantly in the district have not been observed in a granulitic condition. Perhaps these pegmatites were introduced during the period when the quartzose schists and the quartzose parts of the intrusions were undergoing the process of granulitisation. Pegmatites are at least as common in the intrusions as in the schists, and pegmatites have been traced from the schists into an intrusion. Some of the intrusive sills—for instance, the dark hornblendic bands on the north side of Loch nam Breac Mora and in Fionn Allt (about 1000 yards slightly north of east of that lake)—have been sharply contorted together with the schists in which they occur. Both rocks probably suffered some alteration during the time of contortion. The whole region may at that time have conceivably been under such conditions of pressure, depth, and temperature that recrystallisation necessarily ensued in nearly all the rocks.

III. THE EASTERN SCHISTS IN ASSYNT.*

Except in certain places, the position of the Moine thrust-plane in Assynt is well defined. From a point near Gorm Loch Mor it has been traced southwards to the eastern shore of Loch Ailsh, whence, crossing the River Oykell and Allt Ealag, it sweeps westwards to the Knockan Crag south of Elphin. The sequence of rocks above this great line of disruption begins here, as in the ground already described, with mylonised materials, consisting chiefly of quartzose rocks and including a sheared igneous sill. These rocks exposed to the east of Gorm Loch More are followed by fine-grained, flaggy, granulitic schists containing quartz, biotite, and muscovite. They are eventually succeeded by the siliceous flagstones with sills of foliated granite. At this part of the district the normal type of quartz-schists appears within 300 yards to the east of the Moine thrust-plane.

The sheared arkose is not continuous along the strike, but occurs in lenticular form. It is next seen in Allt Chnaip Ghub-

*By B. N. Peach and J. Horne.

hais near the head of Allt Loch Carn nan Conbhairean, where the deformation is equally marked. Among the rocks which have here shared in the movements that affected the Moine schists intrusive sheets of igneous material deserve notice. About 500 yards east of the line of disruption, in one of the branches of Amhainn Gleann na Muic, a tributary of the River Cassley, a thin sill appears in those schists, both having common foliation-planes. It contains greenish-brown biotite, with needles of actinolite in a granular mosaic of felspar, the rock being regarded by Dr. Flett as possibly a sheared kersantite. Again, at the foot of Allt na Cailliche, which drains into Loch Ailsh, several thin sills of sheared syenite porphyry make their appearance, which are characterised by the abundance of porphyritic felspars and of biotite in their ground mass, together with a little quartz.

One stream-section may here be referred to in further illustration of the extreme difficulty of sometimes locating the exact position of the Moine thrust-plane. In a little burn east of Allt na Cailliche, that joins the River Oykell about three-quarters of a mile S.S.E. of Loch Ailsh, where the rocks are continuously exposed, a passage can be traced from recognisable Cambrian zones eastwards into siliceous (Moine) schists without any apparent disruption line. In the lower part of the section sheared pipe-rock with sills of foliated porphyry are succeeded by schistose felspathic arkose, partly granulitised, with streaks of sericitic mica on the divisional planes. The lines of heavy minerals in the original sediment are still apparent, and the pebbles of quartz and felspar have not been effaced. These beds of arkose are traversed by sills of sheared porphyrite with porphyritic orthoclase and crystals of orthite. Eastwards a mylonised quartzite with parallel films of white mica is followed by a band of hornblende-schist, and eventually by siliceous Moine-schist. All these strata including the sheared pipe-rock have a common dip and strike and common planes of schistosity which are more or less parallel with the plane of the Moine thrust. In the River Oykell the beds overlying this line of disruption consist of partly mylonised and partly granulitised rocks which have been driven over sheared fucoid-beds with a sill of foliated syenite porphyry.

Interesting evidence is obtained in the Knockan Burn that deformed grits and sills of igneous material, resembling some of those in the Cambrian strata of Assynt, appear among the Eastern schists. About 100 yards up that stream from the Moine thrust-plane and about a mile south from the Knockan village these schists include a thick sheet of foliated granitic rock, together with thin intrusions sometimes less than an inch thick. These intercalations occur along the foliation-planes of the schists, the parallelism between the two rocks being well marked. Microscopic examination shows that the sediments into which the sills were intruded have not been much altered. One specimen (No. 9758) is a mylonised arkose in which the pebbly structure is not yet destroyed. The sill (9756, 9757) associated with this arkose shows, according to Dr. Flett, phenocrysts of orthoclase, plagioclase, and microcline, which are broken and partly granulitised. The ground-mass contains much biotite with chlorite, and is considerably granulitised. Such cumulative evidence seems to point to the conclusion that beds of arkose, resembling the Torridon rocks to the west and intrusive rocks like those in the thrust masses in Assynt, have shared in the movements that affected the Moine-schists and now form an integral part of these schists.

IV. THE EASTERN SCHISTS BETWEEN KNOCKAN AND STRATH KANAIRD.*

The rock that immediately succeeds the Eilean Dubh dolomite above the Moine thrust-plane on the Knockan cliff is a greenish platy quartzo-felspathic flagstone, including thin intercalations of a more schistose rock with crumpled folia. (See Fig. 40.) Between Lochan Fada and Drumrunie (old) Lodge, in the area west of the Ullapool road, these green corrugated schists, which are there the predominant rocks, exhibit the peculiar structure to which the name of "oyster-shell" or "frilled" schist has been applied in the area where they are typically developed on the east side of Loch Eireboll (*ante* p. 604). Two hundred yards south from the point where the county boundary between Sutherland and Ross crosses the Knockan cliff, a lenticular mass of comparatively unaltered Lewisian gneiss intervenes between the dolomite and the thrust-plane. A short distance further south a lenticle of Cambrian quartzite occupies a similar position. Another lenticular mass of gneiss, which likewise exhibits little deformation, is seen to rest upon the serpulite-grit at the roadside half a mile north of Achendrean, and immediately south of a small burn that here crosses the road. These intercalated masses may be regarded as phacoids, which have to a large extent escaped the deformation that has destroyed the original structures in the surrounding rocks.

Eastwards from the thrust-plane the siliceous flagstones become more crystalline in character and greyer in colour. White mica has been developed in more or less abundance on their divisional planes. Bands of thin fissile mica-schist are associated with the more siliceous variety. Several such highly micaceous bands, containing abundant small garnets, have been traced through the flagstones a mile to the east of Drumrunie Lodge.

The Moine schists in this district have a persistent easterly dip at angles varying from 8° to 15°, but this dip cannot be regarded as in any way indicating the original disposition of the strata. The rocks have been thrown into a series of isoclinal folds, and their dip at any point merely represents their inclination along either limb of one of these folds. Hence no satisfactory computation can be made of the thickness of the materials that

* By L. W. Hinxman.

have been piled up above the Moine thrust-plane. (Fig. 40.) The low angle of inclination of this thrust-plane causes its surface to approximate in many places to that of the ground, and to run for a considerable distance up into Strath Kanaird, where denudation, by exposing the rocks that lie beneath the thrust-plane, has shown the comparatively small thickness of the overlying cake of Eastern schists in this part of the district.

V. THE EASTERN SCHISTS FROM STRATH KANAIRD TO STRATH NA SHEALLAG.*

The Eastern schists in this district offer few points of interest. They do not rise to a greater height than 1830 feet in the highest point, Beinn Eilideach, to the south-east of Ullapool. Their general surface forms plateau-like ground, from about 600 to 1600 feet in elevation, deeply trenched by the valleys of the River Kanaird, the Ullapool River, Loch Broom, and the Strathbeg River. Many of the smaller streams that traverse these rocks have formed in them remarkably narrow, deep, and often quite impassable gorges. Good examples of this feature may be seen near Leckmelm and Ardcharnich on Loch Broom, and a specially striking instance on the larger stream of Strathbeg above Corryhallie. Lochs and lochans are extremely numerous, as in the area north of Loch Achall, and on the plateau between the valleys of Loch Broom and Strathbeg. Most of these waters lie in rock basins, each often occupying a separate depression of the ground, so that without a careful scrutiny of the district many lochs would escape notice. The overlooking of this necessity has doubtless led to the omission of lakes in various places from the Ordnance maps.

The prevailing type among the Eastern schists of this district is the typical granulitic, flaggy, light-coloured quartzose rock, not conspicuously foliated, generally presenting a moderate amount of white mica on the foliation-planes. Scattered through the rock are specks of dark mica or biotite, but these become rarer in the most quartzose varieties. Felspar is generally present, and in some cases forms a considerable portion of the schist. The next most marked type is a dark-coloured biotite-schist with abundant wavy or wrinkled foliation-planes. It is comparatively poor in quartz, but contains also white mica like the siliceous variety, and both rocks often contain small garnets. The biotite-schist occurs as bands in the quartz-schist, the bands varying in thickness from mere partings of a few inches up to beds that form distinct features, and are traceable for some distance. Between these two distinct varieties of rock many gradations may be observed. There are also highly siliceous and massive kinds which approach the nature of quartzite, and contain little mica of any kind. Although the dark biotite-schist forms but a small part of the total thickness of these rocks, it often spreads over an area very disproportioned to its bulk.

* By the late W. Gunn.

In places where the two principal varieties of schist frequently alternate the siliceous kind almost invariably forms the small crags and prominent features, while the biotite-schist, lying as a thin cake on the top of the crag, spreads out over the dip slope.

Probably the finest section of the Eastern schists in this district is to be seen in the great scar on the east side of the Strathbeg River, called Creag Dhuibh Coill a Bhun. From 700 to 900 feet in height it is almost entirely made up of rocks of the siliceous type, here and there banded with beds of biotite-schist two to three feet thick. The foliation dip of these rocks is for the most part regular at angles of 10° to 20°, sometimes rising to as much as 30°. The direction of dip is generally to the south-east. Few signs of much plication can be detected; only gentle undulations are observable. Between Strath Kanaird and the Achall Valley, however, the inclination becomes less regular, being in many places nearly due south, and near Loch Achall north-east. Along certain lines, also, the schists have been much ridged up and contorted, as in the marked example already (*ante* p. 536) described as traceable for several miles in an E.N.E. direction on either side of Loch Broom.

Signs have been observed not infrequently of another kind of deformation in these rocks, where a differential movement has produced friction-marks. In the district north of the Rhidorroch River this movement appears to have been directed towards the north-west or W.N.W. Occasionally also another type of foliation may be noticed, in which, for example, between two slabs of flaggy, regularly-foliated and gently-inclined schist, a bed may intervene, in which the foliation shows a steep dip and is much puckered. This arrangement may be the remnant of an original structure elsewhere destroyed, or it may be that the puckered slab was subjected to differential movement while the adjacent beds remained comparatively motionless.

Segregation veins and pegmatites of a white or pink colour are common in some parts of the Eastern schists of this district. perhaps more abundantly where the rocks have been folded or puckered. Where biotite-schist and quartzose-schist frequently alternate pegmatites appear in the former rock, while in the latter quartz-veins appear to represent the pegmatites. That the crystalline Moine-schists of this district have mainly a clastic origin may be confidently inferred from the traces of clastic material occasionally met with among them. The age of the original sedimentary masses, however, still remains in doubt. In some places, as in the example from the cliffs east of Dundonnell, good evidence can be adduced that altered Torridon Sandstone has entered largely into the composition of the Eastern schists.

The amount of undoubted igneous material in the Eastern schists of this district is small. East of Ullapool a narrow band or sill of granite, among the schists not far east from the Moine thrust-plane, has been traced almost continuously northward to Loch Achall. Intrusive material of the same character occurs north of Glastullich and half a mile south of Loch Achall on the eastern side of the main stream which enters the loch from the south, where the sill is ten feet thick. The rock is a red biotite-granite which contains microcline and white mica, and is often traversed by veins of fine-grained quartz-rock. The shore at Loch Broom, near the south end of Leckmelm Wood, displays a narrow band of similar rock, but as it is distinctly foliated it has become an irregularly-foliated biotite-gneiss.

CHAPTER XLII.

THE EASTERN SCHISTS FROM STRATH NA SHEALLAG TO LOCH ALSH AND IN SKYE.

I. STRATH NA SHEALLAG TO LOCH ALSH.*

In the area between Strath na Sheallag and the lofty crag east of Loch an Nid the position of the Moine thrust-plane is clearly defined. It is noteworthy that the fine-grained, greenish-grey schist which immediately overlies the plane at the south end of that crag is a typical Moine-schist, being composed of a granulitic aggregate of quartz and felspar with scales of white mica and " eyes " of felspar. Southwards, however, on the ridge about 200 yards east of Loch a' Mheallain Odhair and about two miles and a half north of the Heights of Kinlochewe there is a development of green and streaky mylonites, the origin of which is difficult to determine. Some of these rocks may be due to the deformation of bands of Lewisian gneiss, others to the crushing of Torridon grit, and in one instance (Specimen No. 4708) the rock may not improbably be a member of the Moine series, the structure of which has been modified by the post-Cambrian movements.

From the Heights of Kinlochewe southwards to Loch Coulin a zone of green schist, with an apparent thickness of about 250 feet, lies along the base of the Eastern schists and immediately above the plane of disruption. It is composed of flaggy granulitic rocks, with which occur bands of the more siliceous grey flagstones and of the wavy mica-schist similar to the " oyster-shell " type of Loch Eireboll. At the base of this series, about half a mile east of Loch Clair, a highly-contorted platy schist with well-marked striping is evidently of sedimentary origin.

Garnetiferous muscovite-biotite schist or gneiss is remarkably developed on Meall Dubh and Meall ant-Sithe, about two miles east of Loch an Nid and about a mile and a half east of the Moine thrust-plane, the mapping of which has thrown much light on the geological structure of that and adjoining areas. The rock

* By J. Horne and B. N. Peach, with Notes from E. Greenly. The district described in this chapter is contained in Sheets 61, 71, 81, 82, and 92 of the Geological Survey Map of Scotland, on the scale of 1 inch to a mile ($\frac{1}{63360}$).

is variable in character, being composed, in places, mainly of biotite, in others of biotite and muscovite, with knots and lenticles of quartzo-felspathic material. Garnets are abundant, and sometimes form aggregates more than an inch broad.

A notable petrographical type, which has been traced for some distance on both sides of Glen Docherty, is an augen-schist with a normal granulitic matrix, enclosing numerous "eyes" of felspar about half an inch in breadth, which show the effects of crushing. An interesting feature in this rock is the well-rounded form of its felspar "augen," which thus differs from the elongated or phacoidal shapes which have generally resulted from the dynamic movements of this region. Another remarkable zone of biotite-garnet augen-schist, which appears about a mile and a half east of the Heights of Kinlochewe and also on the Sron Dubh north-east of Leckie, is about 45 feet thick, and consists of a massive schist with flakes of dark mica arranged in phacoidal form. It includes fine granular bands with minute garnets. The petrological character of this rock has been described in detail by Dr. Teall.

Around Kinlochewe in the Moine-schists, quartz-bands and rods are numerous and important. Consisting wholly of white granulitic quartz they are exceedingly compact and uniform in texture, and are usually separated from the schists by films of mica. Their foliation-planes are frequently striped or fluted along the dip, the lineation being persistently from the E.S.E. In some places they form regular bands in the schist, elsewhere they appear as rods, and intermediately as flattened lenticles which are generally convoluted. Discordance can frequently be seen between their margins and the foliation-planes of the schists. From their greater durability they often form the crests and dip-slopes of the rock-bosses on the high plateaux. Fine examples of these features abound on the escarpment east of Abhuinn Bruachaig, north of Allt Dubh Leacaidh, and north of Cam na Garbh Lice, where all the stages between perfect rods and unfolded quartz-bands can be found. It is highly probable that these bands are of segregatory origin, and that the rod-structure and granulitisation have been produced by the post-Cambrian movements.

The double system of folding in the Moine-schists (Chapter XL.) is beautifully illustrated in the area between the Heights of Kinlochewe and the plateau north of Glen Carron. The strike of the main folding, save where locally disturbed, is generally N.N.E. or north-east, and the dip varies from E.S.E. to south-east at angles ranging from 18° to 25°. But notwithstanding this persistent inclination towards the E.S.E., the strata are probably reduplicated on an extensive scale, the crests of the folds having been removed by denudation.

From Achnashellach to the head of Loch Carron the Moine thrust-plane is concealed beneath the alluvium of the River Carron and by Loch Dhughaill. The first rocks exposed on the slope south-east of Loch Dhughaill above the position of that plane are frilled schists of phyllitic type, alternating with flaggy quartzose granulitic bands, passing south-eastwards into the typical siliceous flagstones of the Moine series. Further down the valley at Arinackaig and on the north-west declivity of Carn Mor two narrow belts of granulitic biotite-actinolite-gneiss may be inliers of Lewisian rocks, modified by the post-Cambrian movements. To the west of the alluvium around the head of Loch Carron the Moine-schists appear at Kirkton as siliceous flagstones and phyllites, which are let down by a fault against the thrust flaser-gneiss that overlies the Kishorn thrust-plane. (Fig. 54, Chap. XXXVIII.) Southwards this plane of disruption is visible in a stream, not far to the north of the bend of the road leading to Kishorn and about two miles and a half north-west of the village of Loch Carron, where the siliceous schists, much folded and crushed, override the flaser-gneiss.

On the east side of Loch Carron the Moine thrust, though not exposed, must crop out near the railway station at Stromeferry, for mylonites are seen at the pier to the west of the station, and granulitic siliceous schists occur not far to the east. Between Stromeferry and Attadale a narrow strip of siliceous schist, is followed (see Chapter XXXVIII.) by a thin zone of mica-schist containing crystals of hornblende, which passes eastwards into a rock with a similar matrix, enclosing lenticles, a few inches long, of quartzo-felspathic material, together with pebbles and grains of quartz. The rock thus resembles a conglomerate. The largest of the lenticles, from eight to ten inches long, are all elongated in one direction. They may have been derived from the Lewisian gneisses to the east. This so-called conglomerate lies in immediate contact with an overlying mass of granulitic hornblende-biotite-gneiss, which occupies a broad area southwards to Loch Alsh. (Sheets 71 and 81.)

Reference has already been made to the outcrop of the Moine thrust-plane between Stromeferry and Loch Alsh, where the granulitic siliceous Eastern schists have been driven westwards over the thrust flaser-gneiss. (Chapter XXXVIII.) Both at Braeintra and in the hollow between Kirkton and Auchtertyre Hills evidence of the breaking down and crushing of the structures in these schists has been obtained.

The remarkable conglomeratic rock noticed in Chapter XXXVIII., which may possibly mark the base of the Moine series south of Braeintra, is exposed in two places. The first of these lies on the east margin of a belt or infold of siliceous schist about 300 yards west of the bend of the road leading across the ridge towards Gleann Udalain, where it forms an isolated knob peering through drift. The second exposure is visible about 100 yards further to the east in a knoll, where the conglomerate rests on granulitic hornblende-biotite gneiss, and passes eastwards underneath the Moine-schist. In both cases the matrix is holocrystalline, composed of quartz, felspar, hornblende, biotite, muscovite, and epidote, and enclosing fragments of granulitic gneiss and quartz. It is noteworthy that the crystals of actinolite in the matrix pass into the included pebbles.

Eastwards from the Moine thrust-plane towards Gleann Udalain evidence is presented of increasing metamorphism in the Moine-schist on each successive infold. The rocks become more coarsely crystalline and the intervening belts of Lewisian gneiss are almost wholly granulitised. On the east side of the bay at Kirkton of Lochalsh, on the rocky headland south-west of Avernish, a "crush-conglomerate" appears within the area occupied by the Lewisian gneiss, which there consists of hard granulitic quartz-biotite gneiss, mica-schist, and hornblende-biotite-chlorite schist. By a complex system of overfolds, lenticles and knots of the hard siliceous gneiss have been pinched off and isolated in the green chloritic schist, the pseudo-pebbles being elongated in a direction parallel with the long axes of the folds.

II. THE EASTERN SCHISTS IN SKYE.*

In Skye the Eastern schists are confined to the part of the peninsula of Sleat which lies south of Loch na Dal. On the mainland opposite to Kylerhea similar schists strike towards the north-east, and help to connect the Skye exposures with those to the north of Loch Alsh, described in the previous pages. In the area now under consideration these schists are separated by thrusts from all the rocks which can be regarded with confidence as Torridonian, but many of their junctions with the Lewisian gneiss, though much folded, show no indications of thrusting.

The most northerly exposure of the schists on the south-eastern side of the Moine thrust is to be seen in Camas a' Mhuilt, near Isle Ornsay, but is small in size, and wedges out in less than half a mile in a south-westerly direction. About a mile and three-quarters further in the same direction another thin strip of similar schist appears on the same side of the thrust. In Camas Croise, and between that bay and Isle Ornsay, a small much-folded patch is bounded on the west by a fault or thrust striking slightly east of north. South-east of Armadale Bay these rocks appear again, and form Rudha Phoil, Rudha Dubh, and the adjacent islands. South-west of the bay they extend some distance from the shore, but are so mixed with the Lewisian gneiss, partly by folding and partly by lines of crush, which have a prevalent north-easterly trend, that it is difficult to describe their distribution. The coast from 200 yards north of Bogha Charslice to half a mile south-west of Tormore is composed either of Moine-schists or of Tertiary intrusions. Starting from the road a third of a mile N.N.E. of Tormore one may walk in a westerly direction for nearly a mile and a half and keep on Moine-schists all the way. All these rocks within the limits here traced lie on the eastern side of the Moine thrust-plane.

* By C. T. Clough.

A much larger area of these schists lies, however, to the west of that plane. It comes to the coast between Aird and the Point of Sleat, and, together with some small associated patches of gneiss, Torridonian and Mesozoic rocks, extends northward for six or seven miles from the Point of Sleat on the western side of the peninsula, its breadth near Rudh' an Iasgaich being about two miles and a half. Its northern end forms a curve on the hill 700 yards south-east from the east end of Loch Gauscavaig, and is flanked on the north-eastern side by two small outliers, neither of them so much as 60 yards in length, which appear to rest on beds belonging to the Kinloch division of the Torridonian series. Near the north end of this area the boundary between these schists and the Torridonian series is the Tarskavaig thrust, which has been folded into a syncline with axial plane striking to N.N.E. and hading to south-east. (Figs. 65 and 66.) Further south the eastern limb of the syncline becomes vertical, or even dips to south-east or east, so that the Torridonian rocks sometimes overlie the schists. The south-eastern portion of the area is divided from the north-western by the Caradal thrust, the outcrop of which can be traced along the west side of Sleat from Geur Rudha to near Inver Dalavil. It then bends towards east and south-east until it meets the Lamarscaig thrust a mile north of Sgurr nan Caorach. The Caradal thrust repeats the lower portions of the Moine series, which on either side of it present much the same state of alteration. Both portions of the large area now traced lie on the north-western side of, or below, the Moine thrust, whereas all the other areas lie above it. All the schists below that thrust are less altered than those above it, and show their sedimentary character more distinctly. Though the schists on both sides of the thrust must have been originally very similar in character, and in their relations to the Lewisian gneiss, the difference in the extent of their metamorphism will make it convenient to describe them separately.

(i.) Beginning with the rocks on the north-west side of the thrust, distinguished by the name of the Tarskavaig Moine-schists (Chap. XXXIX.), we have to remark at the outset that they are perhaps less altered than any other known Moine-schists. They are, therefore, of particular interest. They may be divided into two types, one chiefly of phyllitic character, the other more siliceous. The phyllitic portion is usually closely intermixed, sometimes in nearly equal proportions, with thin sandy or siliceous streaks. In most places—for instance, near Tarskavaig Bay—the materials next to the Lewisian gneiss consist chiefly of phyllite mixed with thin bands of fine siliceous schist, covered by an alternating series in which the siliceous bands, though in considerable excess of the phyllitic, have a finer grain and a paler grey colour than are usually found in the overlying schistose grits. Some considerable exposures of phyllite—for instance, on the west side of Aird, near Loch Nigheann Fhionnlaidh, and on the north-east side of Sgurr Breac—appear at some distance from the gneiss, but they may nevertheless represent folded portions of the phyllitic beds usually seen near the gneiss.

The clearest junction between the Moine-schists and the gneiss is to be seen on the coast nearly two-thirds of a mile W.N.W. from Loch Nigheann Fhionnlaidh, where phyllite rests on an unctuous green schist which may represent a sheared form of one of the gneiss rocks. The line between the two rocks is slightly waved, but almost parallel to the bedding in the phyllite, the bedding being shown by some thin siliceous bands. The foliations of the two rocks are parallel to one another and slightly steeper than the bedding in the phyllite, and portions of the two rocks are, in places, united into one block. On the north side of Acarseid an Rudha some of the phyllitic bands are slightly calcareous. Thin gritty or pebbly bands, rarely more than an inch thick, are generally abundant in the phyllites, and some of them, even when they show distinct clastic grains of opalescent quartz and red felspar, are calcareous. Good examples of these calcareous bands are exposed on the coast a mile east of Ard Thurinish, and on the north side of Acarseid an Rudha.

On the coast from Port na Long to within a mile of the Point of Sleat the phyllite and the intermixed gritty beds, but perhaps the latter especially, contain many round spots, some as large as small peas, of black mica or chlorite. The rocks containing these spots do not split readily along the foliation-planes, and they "clink" under the hammer. They are also perhaps less lustrous than the phyllites in most parts of the district. Some of the bands of purer phyllite also contain garnets, about the size of mustard seeds, together with little plates of some hard black undetermined mineral lying across the foliation-planes. The spots are evidently of secondary origin, and when examined under the microscope (Nos. 7348 and 7349) the flakes in them are seen to contain many inclusions of the granulitic constituents of the rock, and also to be repeatedly twisted. In some spots they are composed of biotite, in others of chlorite or of chlorite intergrown with biotite. In addition to these minerals many small brownish-red spots, of low refractive index, may perhaps be albite. Similar micaceous spots characterise the schists for a little distance inland from the coast, but further north they become gradually less prominent.

We suppose the spots to have existed before the schists containing them were thrust into their present positions. The flakes in them were perhaps twisted while the thrusts were in progress. As the flakes are later than the granulitic constituents of the rock, it would seem that these Moine rocks were granulitised and essentially in their present condition before the thrusts took place. If this conclusion be admitted, the differences in extent of metamorphism between the Tarskavaig-Moine schists below and the Moine-schists above the Moine thrust existed prior to the thrust. We may suppose that these rocks were pushed from an area in which the metamorphism increased in a south-easterly direction.

The metamorphism which produced the micaceous spots, though probably earlier than the thrusts, must have been later than the regional metamorphism—which was perhaps induced during the isoclinal folding—and may have been developed near some igneous intrusion.

The variations in breadth of the outcrop of phyllite next the gneiss are perhaps in part due to the varying original thicknesses of the bed in different localities. In some places there is no phyllite in this position, and its entire absence could not be explained by folding. The facts seem to suggest that, though we see no clear unconformity between the Moine-schists and the gneiss rocks in any particular section, there may yet be a discordance there, the apparent conformity being due to the dragging into parallelism of the structures of the two rocks.

The schistose grits which come above the phyllites next the gneiss make up much the largest part of the area. They were probably thicker than the phyllites originally. Their quartz grains and pebbles have usually either "run together" to form a granulitic matrix, or else they have been greatly deformed and pulled out into parallel streaks. A bluish opalescent tint, like that of the quartz in the Lewisian gneiss, is still shown by many of the larger grains, even by some which are considerably elongated. Half a mile E.S.E. from Camas Daraich the quartz-pebbles are crossed, in a direction at right angles to that of elongation, by many thin rather opaque white streaks, which are more distinctly granulitic than the other parts of the pebbles. Some of these pebbles are as much as three inches long, though only half an inch broad. Most of the clastic grains and pebbles of felspar consist of red microcline. They are generally much less deformed than the quartz pebbles, and are traversed by cleavage-planes that cross their whole breadth without any noticeable crack or elongation. The difference in the behaviour under shearing of the quartz and felspar grains is particularly prominent in Camas Daraich and 300 yards south of Acarseid an Rudha. In a few places pebbles have been found compounded of red felspar and opalescent quartz. Small grains of epidote are common, sometimes so large and abundant as to be recognisable by the unaided eye, and to give a yellowish-green tint to the rock-matrix. They are usually congregated into streaks parallel with the other stretched constituents of the rock. The micaceous flakes on the foliation-planes are, as in the phyllites, too small to be discerned macroscopically, but in all parts of the district larger flakes, of biotite or chlorite, are usually found to cross these planes at various angles. The average size of the larger clastic grains varies in different bands. It is possible to recognise that in many places the schists are very false-bedded.

Short veins of quartz, or of quartz with a certain proportion of red felspar and chlorite, are common both in the phyllites and more siliceous bands, but are seldom more than an inch or two thick. In a specimen (No. 7354), obtained a quarter of a mile north of Inver Dalavil, the felspar is albite or a closely-allied species, accompanied with some little strings and specks of carbonate. Some of the veins show a rodded structure on the outside, or are crossed by a foliation which also affects the beds in which they occur. The direction of stretching is sometimes —as, for instance, on Rudha Caradal—parallel to the direction of dip, but more usually differs somewhat from it. Between the Point of Sleat and Geur Rudha, and on the coast half a mile north of Inver Dalavil—places where the usual dip is slightly south of east—the stretching is often 35° or 40° more south of east. Rather more than a third of a mile E.N.E. from the centre of Camas Daraich the dip is towards E.S.E., and the elongation almost at right angles to it.

(ii.) Sections of the schists that stretch to the east of the Moine-thrust and overlie it, may be seen on the north side of Camas Croise, on the south side of Rudha Phoil, and from near Bogha Charslice to about half a mile south-west of Tormore. The siliceous schists, representing altered sandstones or grits, are, as already stated, in a more altered state than the corresponding rocks on the north-western side of the thrust. We may search long among them without detecting any clastic grains, nearly the whole of the quartz and felspar being of an authigenic character. Besides this difference the average size of the granules in the granulitic mosaic is greater than in the Tarskavaig-Moine schists, the white mica-flakes on the foliation-planes are larger, and are mixed with many flakes of biotite, while garnets are both more common and of larger size. Veins of quartz and felspar are also thicker and more numerous. Moreover, the specially micaceous schists are much more lustrous than the corresponding rocks—the phyllites—on the other side of the thrust, and the mica-flakes in them are often large enough to be easily distinguished by the unaided eye.

On the east side of Kyle Rhea, and near Camas a' Mhuilt and Allt Bealach na Coise, the rocks next the Lewisian gneiss are granulitic siliceous flagstones. In the schist areas further to the south-west the material lying next the gneiss is in most places a thin pale siliceous schist, covered by a considerable thickness of more micaceous schist with subordinate siliceous beds. A distance of only six or seven miles intervenes between the tracts in which these two types of rock next the gneiss are found, and no great fault or thrust is known to exist in the interspace. It may be suggested that the Moine-schists may overlap the gneiss,, and that those portions of them which lie next the gneiss in the south-western part of the district gradually thin away in a north-easterly direction. No conglomerate or breccia has been detected at the undisturbed junctions of the schists and the gneiss. The clearest of these junctions are to be seen near Tormore and Meall Buidhe. The foliations of the two rocks are parallel, and no structure-lines have been observed in the one rock that cannot be paralleled in the other. The gneiss disintegrates more readily than the Moine-schist, and recedes from it in weathered scars. It also displays somewhat brighter colours, sub-parallel streaks of red and green being common, so that the line between the two rocks can usually be fixed within a few inches.

The rocks which crop out on the coast to the north-west of Bogha Charslice and continue thence to beyond Tormore, extending also for varying distances inland, include a considerable proportion of highly micaceous schists. In some places the siliceous bands preponderate, but none of them have been mapped out except that which lies next to the gneiss. As the more micaceous schists are repeatedly seen near the gneiss, while the more massive siliceous rocks of Rudha Phoil and Rudha Dubh never are, it seems probable that these last rocks come above the former. They may lie on the same stratigraphical horizon as the gritty rocks which form so large a proportion of the Tarskavaig-Moine schists.

The more micaceous schists are usually of a dark-grey or leaden colour. Most of the thin interbedded siliceous bands vary in thickness from one to six inches, and being harder than the micaceous bands they project on the weathered face, where they show the numberless isoclines into which the rocks have been folded. At different places, distant respectively from Tormore half a mile north-east, 300 yards E.S.E., and a quarter of a mile east, some of the siliceous laminæ contain specks of red felspar, about the size of small peas, which show cleavage-planes right across. These are probably clastic grains. A quarter of a mile east of Tormore some large blocks, tumbled from the cliffs above, show alternating thin bands, some of which, as much as six inches thick, are slightly calcareous, and also contain specks, about the size of small peas, of granulitic quartz, more rarely of felspar. The different granules of the granulithic quartz specks adhere together in the weathered face and project somewhat from the calcareous areas around, so that they still resemble pebbles, though thoroughly granulitic. They are also nearly free from mica-flakes, so common in the matrix. Neither the quartz nor the felspar specks are, as a rule, much elongated at this place. Some of the bands which look like old pebbly strata gradually diminish in thickness until they are represented merely by rows of scattered quartz-specks, embedded in a micaceous matrix. The original sediments out of which these metamorphic rocks have been produced appear to have consisted of a close association of fine and coarse materials.

Veins of quartz and felspar, common both in the siliceous and more micaceous schists, occasionally, as, for instance, in Camas a' Mhuilt, have a thickness of as much as 18 inches. The felspar in these veins is generally red, and free from granulitisation. In Specimen No. 7343, from a vein at the north-east end of Eilean Maol, the felspar is plagioclase, either oligoclase or albite. Small specks of carbonate abound in the veins which contain felspar. In some places also large flakes of black mica or chlorite may be observed either within, or at the sides of, the veins.

The directions of stretching often make considerable angles with those of the dip. In Camas a' Mhuilt and Camas Croise, when the dip is towards south-east or east, the stretching is E.N.E., and as the observer looks towards the quarter opposite to that of the dip the stretching lines appear to incline down towards his right hand. In other parts of Camas Croise, moreover, where the foliation-planes are vertical and strike nearly east and west, as one looks towards the north the stretching lines again incline down towards the right.

APPENDIX.

A.—PALÆONTOLOGICAL.

B.—CHEMICAL.

C.—BIBLIOGRAPHICAL.

APPENDIX.

A.—PALÆONTOLOGICAL.

i.—LIST OF PLACES WHERE CAMBRIAN FOSSILS HAVE BEEN COLLECTED.

DURNESS DISTRICT. (Sh. 114.)

1. Old quarry, close to road, Bailamhuic, Durness.
2 Baile na Cille (Balnakiel) Bay, below old church, 1 mile W.N.W. of Durness.
3. On cliff, 500 yards west of Balnakiel old church, 1⅓ mile W.N.W. of Durness.
4. West side of Loch Croisaphuill, opposite manse, ¾ mile west of Durness.
5. On hill-slope, 400 yards S.S.W. of manse, ¾ mile S.W. of Durness.
6. East side of Loch Borralaidh, opposite island, 1¼ mile S.W. of Durness.
7. Pier at Keoldale, 2 miles S.W. of Durness.
8. Quarry at Post Office, Durness.
9. Cnoc Ach na h' Anaile, near road, 2 miles S.S.W. of Durness ("*Serpulite* Grit").
9a. Cnoc Ach na h' Anaile, near road, 2 miles S.S.W. of Durness (*Salterella* Limestone).
9b. Shore at Keoldale road-end.
10. Quarter mile west of Loch Meadaidh, 2 miles south of Durness.
11. Bealach Mor Burn, where road crosses, 3¾ miles south by east of Durness.
12. Hill-slope, near Pictish Tower, south side of burn, ¼ mile from road, 4 miles south by east of Durness.
13. Allt Ach a Chorrain, ¾ mile S.S.W. of Loch Meadaidh, 3 miles south of Durness.
14. Allt Ach a Chorrain, left branch of burn, ¾ mile S.S.W. of Loch Meadaidh, 3 miles south of Durness.
15. River Dionard, Drochaid Mhòr, 5½ miles south by west of Durness.
16. Knoll, west of road, ¼ mile S.S.W. of No. 15 locality.
17. At shepherd's house, Rudha Ghrudaidh, head of west branch of Kyle of Durness, 4 miles S.S.W. of Durness.
18. Streamlet near Ghrudaidh shepherd's house, head of west branch of Kyle of Durness, 4 miles S.S.W. of Durness.
19. Shore cliffs, Port Odhar, 4 miles N.W. of Durness.
20. Eilean nan Cas leac, 4½ miles N.W. of Durness.
21. An Garbh-eilean, 6 miles N.W. of Durness.
22. Dubh-sgeir, near Eilean Hoan, 3 miles east of Durness,

EIREBOLL. (Sh. 114.)

23. An t-Sron, Camas an Duin, 1 mile south of Heilem Inn, Loch Eireboll.

INCHNADAMPH. (Sh. 101, 107.)

24. Roadside, north of Ardvreck Castle, 2 miles N.N.W. of Inchnadamph.
25. Knockan Craig, near Elphin, 11 miles S.S.E. of Inchnadamph.

ULLAPOOL. (Sh. 92, 101.)

26. Ullapool River, 1 mile north of Ullapool.
27. At bridge, ½ mile east of Ullapool.
28. North shore of Loch Broom, 1 mile S.S.E. of Ullapool.
29. Allt Righ Iain, at roadside, 9½ miles south of Ullapool.
30. Burn, 400 yards N.E. of Loch an Nid, 12¼ miles south of Ullapool.

KINLOCHEWE. (Sh. 82, 92.)

31. Abhuinn Bruachaig, 1¾ mile E.N.E. of Kinlochewe.
32. Abhuinn Bruachaig, a little further down stream.
33. Burn, Meall a Ghubhais, 3½ miles W.N.W. of Kinlochewe.

ACHNASHELLACH AND KISHORN. (Sh. 81, 82.)

34. Allt nan Dearcaig, 1½ mile N. of Achnashellach Station.
35. Court Hill, Kishorn.

SKYE. (Sh. 71.)

36. Top of limestone knoll, Suardal, 1½ mile south of Broadford Hotel.
37. West side of Bealach a Ghlinne, 1¾ mile south of Broadford Hotel.
38. South slope of Ben Suardal, 2½ miles S.S.W. of Broadford Hotel.
39. Ben Suardal, side of Bealach a Ghlinne, 1½ mile south of Broadford Hotel.
40. West side of Ben Suardal, 2 miles S.S.W. of Broadford Hotel.
41. Slope, east of turnpike road, Suardal.
42. At Loch Lonachan, 3 miles south of Broadford Hotel.
43. Slopes, north and N.W. of Loch Lonachan, 2¾ miles south of Broadford Hotel.
44. Slope, west of Allt a Mhuilinn, 1¾ mile south of Broadford Hotel.
45. Shore of Loch Slapin, 5 miles S.W. of Broadford Hotel.
46. Shore of Loch Eishort, ½ mile north of Ord, 6 miles south of Broadford Hotel.
47. Burn at head of wood, ¾ mile east of Tokavaig, 7½ miles south of Broadford Hotel.

ii.—LIST OF FOSSILS FROM THE OLENELLUS-ZONE (LOWER CAMBRIAN).

	Lower Cambrian (Olenellus-Zone).				Locality Number.
	Quartzites.	"Fucoid" Shales.	Serpulite Grit.	Ghrudaidh Limestone.	
ECHINODERMATA.					
Eocystites, *Billings*					
,, sp.		×			29, 32, 34.
ANNELIDA.					
Boring annelides		×			33.
Planolites (worm casts)				×	
Scolithus, *Haldeman*					
,, linearis, *Halde.* ...	×				
,, sp. II. (common pipes)	×				
,, sp. III. ("trumpet" pipes) = Arenicolites, *Salter* ...	×				
Worm Castings (so-called Fucoids)		×			
ANNELIDA (?)					
Coleoloides, *Walcott*					
,, sp.		×			29.
Hyolithes, *Eichwald*					
,, terranovicus, *Wal.* ...		×			29.
,, sp.		×			23, 24, 25, 26, 28, 29, 30, 32, 3 34.
Salterella, *Billings*					
,, (Serpulites), Macculochi (*Salt.*) ...			×	×	9, 9b, 17, 18, 23, 24, 26, 27, 2 29, 30, 32, 34.
,, pulchella, *Bill.* ...		×		×	9a, 16, 23, 24, 26, 27, 28, 29, 3 34, 35.
,, rugosa, *Bill.*				×	16, 23, 24, 26, 27, 28, 29, 31, 3 35.
,, sp.		×			29, 47.
BRACHIOPODA.					
Acrothele, *Linnarsson*					
,, subsidua, *White* ...		×			29, 33.
Paterina, *Beecher*					
,, (Kutorgina) labradorica, *Bill.*		×			33.
TRILOBITA.					
Bathynotus, *Hall*					
,, holopyga (?), *Hall*		×			33.
Olenelloides, *Peach*					
,, armatus, *Peach* ...		×			33, 47.
Olenellus, *Hall*					
,, gigas, *Peach*		×			29, 33.
,, intermedius, *Peach* ...		×			33.
,, Lapworthi, *Peach* ...		×	×		25, 26, 29, 30, 32, 33, 47.
,, ,, var. elongatus, *Peach*		×			33.
,, reticulatus, *Peach* ...		×			23, 29, 33, 47.
,, sp.		×			33.
Trilobite fragment (not Olenellus)		×			46.
PHYLLOCARIDA.					
Aristozoe, *Barrande*					
,, rotundata, *Wal.* ...		×			29.
Nothozoe, *Barrande*					
,, sp.		×			29.
GASTEROPODA.					
Helenia, *Walcott*					
,, bella, *Wal.*		×			29, 33.
Murchisonia (?)					
,, sp.		×			47.

iii.—LIST OF FOSSILS FROM THE CAMBRIAN SYSTEM ABOVE THE OLENELLUS-ZONE.

Species.	Horizon.						Locality Number.	REMARKS. Foreign Horizons and Localities.
	Sailmhor Group.	Sangomore Group.	Balnakiel Group.	Croisaphuill Group.	Durine Group.	Skye.		
SPONGIDA.								
Archaeocyphia, *Hinde*								
,, minganensis, *Billings*			×	×		×	12, 19, 21, 36, 37, 38, 39, 40, 43.	Calciferous. Mingan Islands, Canada.
,, sp.			×	×		×	19, 36, 37, 39, 41.	
Calathium, *Billings*								
,, (Receptaculites) Anstedti, *Bill.* ...			×			×		
,, ,, calciferum, *Bill.* ..						×	36, 40.	,, ,, ,,
,, ,, elegantulum, *Bill* ...						×	37, 39.	,, ,, ,,
,, ,, pannosum, *Bill.* ...						×	42, 43.	No. 2 Quebec Group." Point Lévis, Canada.
,, ,, sp.			×	×		×	12, 19, 36, 37, 38, 40, 42, 43.	NOTE.—In Newfoundland the genus ranges from G.-K. of Billings' Table.
Rhabdaria, *Billings*								
,, sp.			×	×		×	36, 37, 39, 40, 43, 44.	Calciferous. Mingan Islands, Canada.
Trichospongia, *Billings*								
,, sp.			×	×		×	36, 38, 40, 43.	,, ,, ,
Sponge, *indet.*			×	×		×	12, 19, 21, 36, 37, 42, 43.	
ACTINOZOA.								
Coral (?)			×				12	
TRILOBITA.								
Asaphus, *Brongniart*								
,, (Isotelus) canalis (?), *Conrad.*	×						10.	Zones F.-M. of Billings. Port au Choix, Point Rich, Table Head, Bonne Bay, Newfoundland.
Bathyurus, *Billings*								
,, Nero, *Bill.*...				×			21.	Zones F., G., H. & N. of Billings. Port au Choix, Cape Norman, Newfoundland.
,, sp.			×	×			● 12, 21.	The genus Bathyurus ranges from B. to P. of Billings. Table Head, Newfoundland.
?*Conocoryphe Corda*								

iii.—List of Fossils from the Cambrian System above the Olenellus-Zone—*Continued.*

Species.	Horizon. Sailmhor Group.	Sangomore Group.	Balnakiel Group.	Croisaphuill Group.	Durine Group.	Skye.	Locality Number.	REMARKS. Foreign Horizons and Localities.
Trilobita—*continued.*								
Conocoryphe (Conocephalites) chippewaensis, *Owen*			×	×			19, 21.	
,, sp.			×				19.	The genus Conocoryphe is confined to the Cambrian Formation.
Solenopleura, *Angelin*								
,, tumida (?), *Walc.*						×	43.	Olenellus zone. Washington County, New York, U.S., America.
Olenoid trilobite (? Ellipsocephalus, *Schl.*)				×			21.	Middle and Upper Cambrian.
Trilobite, fragment of (? Lonchocephalus=Conocephalites=Conocoryphe)				×			5.	
Brachiopoda.								
Camerella, *Billings*								
,, antiquata, *Bill.*			×	×			5.	Olenellus-zone. Swanston, Vermont, U.S., America.
Orthis, *Dalman*								
,, sp.				×			21.	
Orthisina, *D'Orbigny*								
,, festinata, *Bill.*				×		×	21, 43.	,, ,, ,,
,, grandæva (?), *Bill.*...						×	43.	Calciferous. Canada.
,, (Orthis) striatula, *Salt.*			×			×	4, 12, 43.	
Lamellibranchiata.								
Euchasma, *Billings*								
,, Blumenbachi, *Bill.*			×	×		×	12, 19, 21 36, 38, 43.	Zones G. & H. of Billings. Port au Choix, Table Head, Cape Norman, Newfoundland. Clear Water Point, Mingan Islands, Canada.
,, ,, var. I.				×		×	21.	
,, ,, ,, II.			×	×		×	19, 21.	
,, ,, ,, III.				×			21.	
,, ,, ,, IV. (Eopteria) ...				×			21.	Quebec Group. Port au Choix, Newfoundland.
,, sp.			×	×			42.	

GASTEROPODA.								
Bellerophon, *Montfort*								
,, (Cyrtolites) palinurus (?), *Bill.* ...				×			21.	Quebec Group. Stanbridge, Eastern Canada.
Chelodes (*Davidson and King*)								
,, (Chiton) sp.						×	36.	
Euomphalus, *Sowerby*								
,, (Oriostoma) sp. III.			×				3, 4, 12.	
,, ,, sp. IV.			×	×			2, 21.	
Holopea, *Hall*								
,, leiosoma, *Bill.*				×			21.	No. 3 Limestone, Quebec Group. Point Lévis, Canada.
,, Ophelia, *Bill.*			×			×	36.	Quebec Group. Point Rich, Newfoundland.
Maclurea, *Lesueur*								
,, acuminata, *Bill.*						×	36.	Zones K.-M. of Billings. Table Head and Point Rich, Newfoundland.
,, crenulata, *Bill.*			×	×		×	5, 19, 20, 31, 36, 37, 39, 45, 53.	Zones J., K., L. & M. of Billings. Table Head and Point Rich, Newfoundland.
,, Emmonsi, *Bill.*						×	36, 41, 43.	Zones J., K., L. & M. of Billings. Table Head and Point Rich, Newfoundland.
,, oceana, *Bill.*			×	×		×	2, 5, 12, 14, 19, 20, 21, 36, 37. 38, 39, 40, 41, 42, 43.	Zones F., G., H. of Billings. Pistolet Bay, Port au Choix, Cape Norman, Newfoundland.
,, Peachi, *Salt.*			×	×		×	1, 2, 13, 19. 21, 36, 37, 38, 39, 40, 41, 43, 45.	
,, sp. I. (operculum)			×	×		×	1, 2, 21, 36, 37, 39, 43. 44.	Cf. operculum of M. matutina. Geology of Canada, p. 115, fig. 25. Calciferous Group. Lake St. Louis.
,, sp. II. ,, ...			×	×		×	12, 19, 21, 36, 37, 38, 39, 40, 41, 43.	Cf. operculum, Palæozoic Fossils of Canada, p. 243, fig. 229.
,, sp. III. ,, ...			×			×	36, 37, 38, 39, 40, 41, 43. ...	Cf. operculum, Palæozoic Fossils of Canada, p. 243, fig. 288.
,, sp. IV. ,, ...			×	×		×	19, 20, 36, 40, 41, 43.	Cf. operculum, Palæozoic Fossils of Canada, p. 243, fig. 230. Zones F., G., H. of Billings' Table. Cape Norman, Newfoundland.
,, sp. V. ,, ...			×	×		×	5, 36, 37, 43, 44.	
Murchisonia, *D'Archiac et De Verneuil*								
,, (Ectomaria) Adelina, *Bill.*			×	×		×	12, 20, 43.	Zone G. of Billings. Calciferous. Cape Norman, Newfoundland.
,, (Hormotoma) angulocincta, *Salt.*								
,, ,, Anna, *Bill.*			×	×		×	5, 19, 20, 21, 38, 45.	Calciferous. Canada.
,, ,, antiqua, *Donald.*				×			21.	
,, Artemesia, *Bill.*			×	×		×	12, 20, 37, 43.	Calciferous. County of Leeds and Grenville, Canada.
,, Augustina (?), *Bill.*			×			×	19, 36, 38.	Zones H.-K. Pistolet Bay, Point Rich, Table Head, Burnt Cape, Newfoundland.
,, bellicincta, *Hall*			×			×	2, 19.	Trenton and Hudson River Group. New York, U.S. America.

iii.—List of Fossils from the Cambrian System above the Olenellus-Zone—*Continued.*

Species.	Horizon. Sailmhor Group.	Sangomore Group.	Balnakiel Group.	Croisaphuill Group.	Durine Group.	Skye.	Locality Number.	REMARKS. Foreign Horizons and Localities.
Gasteropoda—*continued.*								
Murchisonia (Lophospira) borealis, *Donald.* ...			×	×		×	2, 12, 21, 36, 39.	Trenton and Hudson River Group. Allumette Island, Canada.
,, **(Hormotoma)** gracilis, *Hall*			×	×	×	×	2, 4, 5, 7, 8, 12, 19, 20, 22, 37.	Black River Limestone, Loraine and Hudson River Group. Pauquette Rapids, River Ottawa, Canada.
,, ,, gracillima, *Salt.*			×	×	×	×	2b, 4, 5, 7, 8, 12, 19, 20, 22, 37.	
,, **linearis,** *Bill.*			×	×			5, 12, 20, 21.	Calciferous. Birch Island, Mingan Islands, Canada.
,, **(Ectomaria)** pagoda *Salt.*			×			×	2, 36, 38, 41, 45.	Black River Limestone. Pauquette Rapids, River Ottawa, Canada.
,, ,, ,, var. orientalis, *Donald.*				×		×	21, 36, 37, 39, 41, 43.	
,, ,, ,, var. Peachi, *Donald.*			×	×		×	5, 12, 20, 37.	
,, sp.	×					×	10, 19, 39.	
Ophileta, *Vanuxem*								The genus Ophileta ranges from E.-P. of Billings. Table Bay, Newfoundland.
,, **compacta,** *Salt.*			×	×		×	2, 13, 38.	Calciferous Sand Rock. Beauharnais, near Montreal. (O. compacta occurs abundantly in the Chazy and Bird's-eye Limestone, N. America, which takes its name from the abundance of this fossil.)
,, **complanata,** *Vanx.*						×	43.	Calciferous division.
,, **Nerine,** *Bill.*						×	37, 43.	Zone F. of Billings. Bay of St. John's, Newfoundland.
,, **sp. I. (n.s.)**			×				10.	
,, **sp. II.**				×			21.	
,, **sp. III.**			×				2, 3.	
,, **sp. IV. (n.s.)**			×					
,, **sp.**						×	22, 43.	
Oriostoma, *Lindström*								
,, **(Pleurotomaria)** Calphurnia, *Bill.* ...			×	×		×	12, 20, 21, 43.	Quebec Group. Cape Norman, Newfoundland.
,, ,, ,, var. I. ...			×	×		×	12, 21.	
,, ,, ,, var. II. ...			×	×		×	3, 5, 14, 20, 21, 22.	

Oriostoma, sp.			×	×		×	2, 5, 19, 36, 42, 43.	
,, sp. (near Pleurotomaria : ribbed) ...						×	37.	
Pleurotomaria, *Defrance*								
,, Arabella (?), *Bill.*			×				19.	Calciferous. County of Leeds and Grenville, Canada.
,, beekmanensis (?), *Whitf.*			×	×		×	12, 21, 45.	
,, calcifera, *Bill.*			×	×		×	5, 12, 19, 21 36, 37, 40, 42, 43.	Calciferous.
,, canadensis, *Bill.*			×				19.	Calciferous. County of Leeds and Grenville, Mingan Islands, Canada.
,, Dryope, *Bill.*			×				2, 12.	Black River Limestone. Pauquette Rapids, Ottawa River, Canada.
,, Etna, *Bill.*	×			×			10, 21.	Zone G.-H. of Billings. Cape Norman, Table Head Newfoundland.
,, gregaria, *Bill.*			×	×			20.	Calciferous. St. Genevieve Island, Mingan Islands, Canada.
,, laurentina, *Bill.*				×		×	21, 36, 37, 38, 40, 42, 43. ..	Calciferous. County of Leeds and Grenville, Mingan Islands, Canada.
. sp. (near to do.								
,, Ramsayi, *Bill.*	×			×		×	10, 11, 21, 36.	Calciferous IIa. Mingan Islands, Canada.
,, (Helicotoma) spinosa (*Salt.*) ...			×	×			12, 21.	Black River Limestone. (?) Chazy. Pauquette Rapids, Ottawa River, Canada.
,, Thule, *Salt.*			×				3.	
,, (Holopea) turgida, *Hall*				×		×	21, 36, 38, 40, 43.	Very near to Murchisonia ventricosa. Calciferous and Trenton Horizons. North America.
,, sp.			×			×	12, 19, 20, 37.	
CEPHALOPODA.								
Actinoceras, *Bronn.*								
,, sp.			×				2.	
Cyrtoceras, *Goldfuss*								
,, sp. I.	×		×				2, 10.	
,, sp. II.			×				2, 10.	
,, sp. III.			×				2.	
,, sp. IV.			×				3.	
,, sp.	×						11.	
Endoceras, *Hall*								
,, sp. I.			×	×		×	21.	
,, sp. II.			×	×		×	21.	
,, sp.			×	×		×	12, 21, 36, 37, 40, 43.	
? Orthoceras, *Breynius*								
,, arcuoliratum, *Hall* (siphuncle of an Endoceras)			×					Black River Group and Trenton Limestone Horizons, North America.
,, baculoides, *Blake* ,,			×			×	4, 36.	Probably a siphuncle of Endoceras.
,, durinum, *Blake* ,,			×			×	12, 19, 20, 21, 36, 7, 43, 44.	,, ,, ,,
,, (Actinoceras mendax, *Salt.*			×	×		×	6, 12, 19, 21, 22, 36, 37, 39, 40, 42, 43.	Calciferous Sand Rock. " See Billings' O. Lamarcki, Mingan Islands, Canada. Also O. Priamus, Point Rich, Pistolet Bay, Newfoundland.

iii.—LIST OF FOSSILS FROM THE CAMBRIAN SYSTEM ABOVE THE OLENELLUS-ZONE—*Continued.*

Species.	Horizon. Sailmhor Group.	Sangomore Group.	Balnakiel Group.	Croisaphuill Group.	Durine Group.	Skye.	Locality Number.	REMARKS. Foreign Horizons and Localities.
CEPHALOPODA—*continued.*								
?Orthoceras pertinens, *Blake*			×	×		×	6, 12, 19, 20, 21, 36, 37, 38, 39, 41, 43.	
,, undulostriatum, *Hall* (= O. durinum, *Blake* (siphuncle of an Endoceras)			×	×			12, 19.	The form identified by Salter as O. undulostriatum, *Hall*, is evidently the O. durinum of Blake, which is probably the siphuncle of an Endoceras.
,, vertebrale, *Hall* (= O. mendax, *Salt.* =O. olorus, *Hall*)			×	×			2, 12, 21.	
,, n. sp. (tapering rapidly)	×						10.	
,, sp.			×	×		×	2, 12, 19, 20, 21, 36, 41, 45.	
Piloceras, *Salter*								The American species of Piloceras range from zones F.-I. of Billings' Table.
,, invaginatum, *Salt.*			×	×		×	3, 12, 19, 21, 36, 37, 38, 39, 40, 43.	In Newfoundland in the Calciferous of Lachute and in the Bird's-eye and Chazy Limestone, Fort Cassin, Vermont, U.S. America.
,, ,, var. I.			×	×		×	40.	
,, ,, var. II.			×	×		×	12, 20, 21, 36, 37, 38, 43.	
,, ,, var. III.			×			×	12, 36, 43.	
,, sp.			×			×	2, 19, 39.	
Trocholites, *Conrad*								Billings records several species of Nautilus from zones F.-K., Newfoundland.
,, (Nautilus) sp. I.			×	×		×	5, 12, 21.	
,, ,, sp. II.			×	×			5, 12, 21.	
,, ,, sp. III.			×				20.	
,, ,, sp. IV.			×	×			5.	
,, sp.			×	×		×	1, 11, 19, 36, 42, 43.	
INCERTÆ SEDIS.								
Ianolites, *Nicholson*	×		×	×		×		Abundant in certain horizons of the limestones of the *Olenellus*-zone and of the Calciferous Sand-rock of N. America.

B.—CHEMICAL.

AN EXAMINATION OF DOLOMITES FROM DURNESS

BY W. POLLARD.*

Specimen No.

8129. Quarry, 150 yards east of Sango Bay. Mottled dolomite. Crystals of carbonate, mostly with irregular outlines, from ·1 to ·3mm. diameter. Occasional small veins of limonite (?) between the crystals. The mottling seems to be due to very minute black grains included in many of the crystals. The crystals which outline the dark patches in the rock appear to contain more of these black inclusions.

8130. Eilean Hoan. Crystals of carbonate, mostly with irregular outlines, from ·08 to ·2mm. diameter. Occasional grains and veins of limonite. Some very minute black grains as inclusions, less plentiful than in No. 8129.

8131. From the Eilean Dubh group, Eilean Hoan. Compact carbonate rock. Crystals of dolomite, with irregular outlines, from ·005 to ·003mm. diameter, and occasional quartz grains of about the same size. Small veins and patches of limonite.

8132. Dolomitic limestone in fucoid shales, near Ghrudaidh. Impure carbonate rock with limonite (?) rounded grains of quartz, and a pleochroic mineral, possibly hornblende. The crystals of carbonate vary considerably in diameter (from ·6 to ·05mm.). The rock is obviously of organic origin.

8133. Big Croisaphuill. Bands of crystalline carbonate (crystals about ·2mm. in diameter) with some limonite, and crypto-crystalline silica, containing crystals of carbonate (from ·1 to ·2mm. diameter). There are minute black grains, possibly carbon, included in the dolomite crystals. (From the analysis given later, it will be seen that the crystals in the bands of crypto-crystalline silica are almost entirely calcite.)

8283. Eilean Dubh group, A'Ghoil Sgeir, near Eilean Hoan. Compact carbonate rock. Crystals of carbonate, with more or less irregular outlines, occasional veins of limonite, and small carbonate crystals. Some short veins of micro-crystalline-quartz. In the slice there is one patch of carbonate crystals, larger than the main mass, with V-shaped markings of limonite, probably formed by decomposition of crystals of siderite.

* This report was prepared at the end of 1898.

The specific gravity of these rocks shows a very small variation comparatively, as is seen by the following list:—

SPECIMENS WHICH HAVE BEEN SLICED.

Specimen No.		
8129.	Quarry, 150 yards east of Sango Bay, Durness,	2·84
8130.	Eilean Hoan, 2½ miles east of Durness,	2·85
8131.	Eilean Hoan, Durness,	2·82
8132.	Dolomitic limestone in fucoid shales, near Ghrudaidh, Kyle of Durness,	2·81
8133.	Big Croisaphuill—Coarse part (dolomite),	2·78
	Compact part (calcite and silica),	2·67
8283.	Eilean Dubh group, A'Ghoil Sgeir, near Eilean Hoan, Durness,	2·85

The specific gravity of the other specimens is as follows:—

Collector's No.			
M. 2882.	Eilean Dubh, Durness,		2·85
„ 2883.	„ „ group, Sailmhor,		2·83
„ 2884.	„ „ base of mottled group, Sailmhor,		2·85
„ 2885.	„ „	max.	2·86
„ 2886.	Mottled limestone, Eilean Hoan,		2·84
„ 2887.	Dolomitic „ „ „ 2½ miles east of Durness,		2·83
„ 2888.	Middle of mottled group, east of Sailmhor,		2·85
„ 2890.	Flaggy beds, middle of Eilean Dubh group, near Sailmhor,		2·82
„ 2891.	Dolomite above chert, base of Sangomore group,		2·81
„ 2896.	Near top of mottled group, Sailmhor,		2·84
„ 2897.	Limestone Skerry, Baile na Cille Bay,		2·82
„ 2901.	Overlying chert bed, Sangomore,		2·84
„ 2903.	„ „ „ „		2·84
„ 2905.	Thin band of dolomite in Big Croisaphuill, east side of L. Borralaidh,		2·84
„ 2907.	About middle of mottled group, Sailmhor,		2·84
„ 2911.	Roadside, 250 yards east of Sangomore,		2·83
„ 2913.	Top of Eilean Dubh, Sailmhor,	max.	2·86
„ 2916.	Limestone Skerry, Baile na Cille Bay,		2 85
„ 2918.	„ „ „ „		2·80
„ 2919.	„ „ „ „		2·85
„ 2920.	„ „ „ „		2·84
„ 2921.	„ „ „ „	min.	2·73
„ 2922.	„ „ „ „		2·82
„ 2923.	„ „ „ „		2·84
„ 549d.	*Salterella* Series, Ghrudaidh group,		2·85

The highest (2·86) are M.2885 and 2913. The lowest (2·73) M.2921, as the compact part of Big Croisaphuill, cannot well be considered, consisting, as is seen from the analysis, of over 50 per cent. of silica. It seems that the above specimens are in all probability all dolomites (with perhaps one or two exceptions) of a greater or less degree of purity. A chemical analysis was made of the six specimens which were sliced, the results of which are given below. Attention should be drawn to No. 8132. The analysis given is from a sample taken from the hand specimen near to where it was sliced. Later on some of the residue was wanted for a microscopical examination, and a fresh chip was taken from the hand specimen. The amount of residue in this sample was over 5 per cent. lower than in the first one. It is probable that the amount of residue would vary considerably in different samples of the rock.

Nos. of specimens	8129	8130	8131	8132	8283
Specific gravity	2·84	2·85	2·82	2·81	2·85
Part insol. dil. HCl.	1·83	2·42	15 81	28·96	2·01
SiO_2	·16	·11	·29	·49	·07
FeO	—	·34	·32	1·52	·35
Fe_2O_3 / Al_2O_3	·21	·28	36	·29 / ·50	·10
P_2O_5	trace (?)	trace	·05	·62	trace
MnO	·17	·24	·19	·33	trace
CaO	29·65	30·05	25·40	21·73	30·09
MgO	21·53	20·25	18·24	13·61	20·83
CO_2	46·62	46·15	39·65	31·45	46·59
H_2O (at 105°C.)	—	—	—	·09	·28
H_2O (above 105°C.)	—	—	—	70	
	100·17	99·84	100·31	100·29	100·32

	Ratio of CaO	:	MgO	:	CO_2
8129	1	:	1·02	:	2·0
8130	1·06	:	1	:	2·07
8131	1	:	1	:	1·99
8132	1·14	:	1	:	2·10
8283	1·03	:	1	:	2·03

Note.—A rough analysis of M.2921, specific gravity 2·73, gave Insoluble Residue 19·9 per cent., Fe_2O_3, Al_2O_3, 1·7, MgO 4·4, CaO 38·0—so this is a dolomitic limestone, not a dolomite. The specific gravity showed it was probably a limestone.

Specimen No.

8129. The residue insoluble in hot dilute hydrochloric acid was blackish. About 50 grams of the rock was dissolved in HCl., the residue boiled three or four times with fresh changes of HCl. finally washed by decantation and dried at 100°C. Under the microscope a fine black powder was observed, mixed with the silica, &c. On igniting the powder it became white, and ignited with copper oxide CO_2 was given off. The loss on ignition of this residue was about 3·4 per cent., or, calculated on the original rock, ·06 per cent. Hence the mottling is probably due to finely-divided carbon in the rock, and about ·06 per cent.

8131–8132. The residue, insoluble in acid, consists mainly of silica, with some iron and alumina.

8133. Big Croisaphuill. The compact part was separated from the crystalline part and the two analysed separately.

	Coarse Crystalline part.	Compact part.
Specific gravity	2·78	2·67
Part insol. HCl	1·73	56·01
SiO_2	·13	·22
FeO	·16	·27
Fe_2O_3, Al_2O_3	·13	
MnO	·25	trace
CaO	32·54	22·43
MgO	19·06	1·40
CO_2	45·82	19·24
H_2O	—	·31
	99·82	99·88

The ratio CaO : MgO : CO_2 in the crystalline part is 1·16 : 1 : 2·09, so there is probably a small amount of calcium carbonate with the dolomite.

The residue of the compact part consists almost entirely of silica (99·2 per cent.). Crypto-crystalline silica usually contains a considerable amount of water (2 per cent. or more), but in this case there is hardly any.

From the above analyses and specific gravity determinations, practically all these specimens are *dolomites*. Nos. 8132 and 8133 (crystalline part) contain rather more $CaCO_3$ than is required for dolomite.

A number of analyses of limestones from Sutherlandshire were made by Dr. Anderson [*Report of the Highland and Agricultural Society*, 1851–53, p. 273], twelve of which are more or less of interest in connection with this district. The localities are given below with percentage of $CaCO_3$ and $MgCO_3$.

		$CaCO_3$	$MgCO_3$
4	Knockdu Elpine, bluish grey	41·58	33·47
5	„ „ greenish grey with marble-like texture	53·77	41·01
6	Durness	90·01	6·50
7	Eireboll, from seaside	51·04	41·36
8	„ powdered limestone	49·50	40·85
9	Achmore, pale blue-grey	53·51	43·20
10	„ darker and more crystalline	54·88	41·85
11	Stronchrubie, white crystalline	45·79	48·72
12	„ dark grey	48·00	42·01
13	Kirktown	50·21	41·22
14	Ledbeg, nearly white crystalline	90·6	8·2
15	„ grey and earthy	51·33	41·08

Dr. Anderson points out that the large amount of magnesium prevents these limestones from being of much use in agriculture.

Professor Heddle (*Min. Mag.*, iv., 239) quotes Dr. Anderson's analyses and gives three analyses of Durness limestone.

It may be of interest to give the following two analyses of specimens from Strath, Skye, which were made for Mr. Harker.

Specimen numbers ..	8063	8064
Specific gravity	2·85	2·86
Part insol. HCl.	2·26	1·72 (Part insol. HCl and SiO_2)
SiO_2	·50	
Fe_2O_3, Al_2O_3	·45	·34
MnO	·22	·19
CaO	30·50	30·53
MgO	21·19	20·81
CO_2	44·54	46·25
	99·66	99·84

	Ratio of CaO :	MgO :	CO_2
8063 . .	1·03 :	1	: 1·91
8064 . .	1·05 :	1	: 2·02

It is most probable that where there is more CaO than the amount required by the MgO to form dolomite the CaO is present (combined with CO_2) as calcite; that is to say that the specimen is mainly dolomite, with a little calcite [as in 8132 and the crystalline part of 8133]. The action of 1 per cent. HCl was tried on one of Mr. Harker's specimens for varying lengths of time (15 and 25 minutes about) and the ratio of CaO : MgO, which was dissolved, determined. Two parallel experiments with a mixture of calcite and magnesite (in the proportion of $CaCO_3 + MgCO_3$) were also made. In the case of the dolomite the ratios were 1·03 CaO : 1 MgO and 1·06 : 1, whilst in the mixture 1·4 CaO : 1 MgO and 1·6 CaO : 1 MgO. The ratio of CaO : MgO dissolved by water saturated with CO_2 at ordinary temperatures was tried on the same sample and on a sample of 8129 (M.2895). A blind experiment with calcite and magnesite was made also.

In the case of the dolomites the ratio was CaO : MgO = 1·3 : 1 and 1·01 : 1, whilst in the blind the ratio was CaO : MgO = 5·9 : 1. It seems hence practically certain that we have true dolomites, and not mixtures of calcite and magnesite.

It would be interesting to examine the behaviour of dolomitic limestones, which contain more calcium and less magnesium than true dolomite, in dilute acids, as, although much has been done in that direction, the results vary greatly. [References given in Zirkel *Petrographie*, vol. iii., 1894, p. 495.] [Action of CO_2 Doelter & Hoernes *Jahrb d. K.K. Geol. Reichst.*, xxv., 300.]

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DESCRIPTION OF PLATES.

PLATE XL.

1. (5013).—Hornblende-rock, from a basic lenticle in gneiss N.N.W. of Rona.

Iron-ores in a matrix composed of irregular grains of gree blende. See page 48.

2. (3398).—Hornblende-rock; × 35. At bend of road, no of Loch Dhrombaig, about one mile east-south-east of Oldany

Confused aggregate of a nearly colourless and usually fibro blende, with some iron-ores. The rock is probably a pyroxenite. See page 47.

Plate XL.

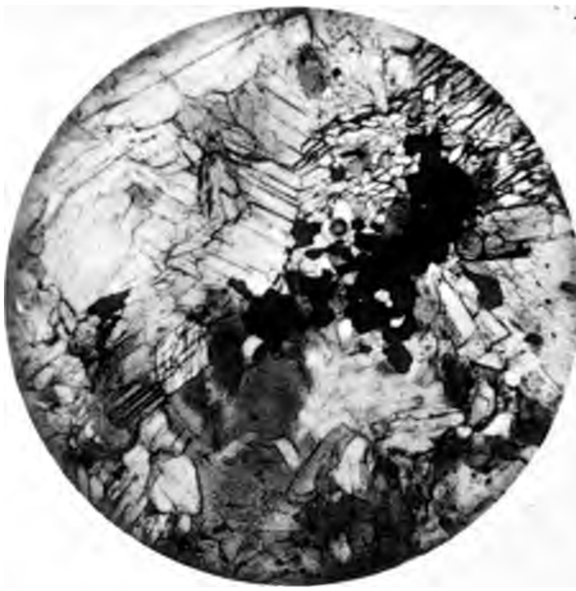

Fig. 1. Hornblende Rock. x 35.

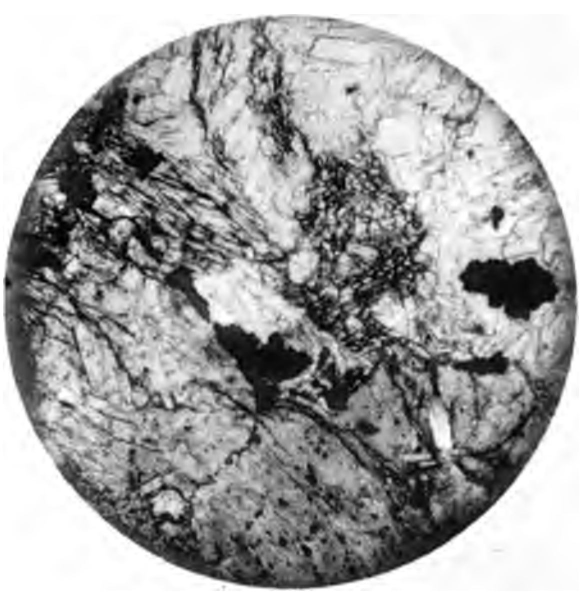

Fig. 2. Hornblende Rock x 35.

PLATE XLI.

1. (3419).—Hornblende-anthophyllite-rock; × 35. Glac a' Mhin Ath, about a mile and a half E.S.E. of Laxford Bridge.

Colourless anthophyllite and green hornblende. A cross-section of anthophyllite lies a little to the north-east of the centre of the figure and on the south-east side of a longitudinal section of the same mineral. See page 49.

2. (4651).—Calc-anthophyllite-rock; × 35. South of Allt Mòr, Geisgeil.

Anthophyllite, calcite, and iron-ores. The anthophyllite occurs as long, cross-jointed prisms in a matrix of crystalline, granular calcite. See page 49.

Plate XLI.

Fig. 1. Hornblende-anthophyllite rock. x 35.

Fig. 2. Calc-anthophyllite rock. x 35.

PLATE XLII.

1. (3036).—Hornblende-gneiss (basic);
Ceannabeinne, Durness.

The two principal constituents are green
(oligoclase-andesine). Quartz and iron-ore
page 59.

2. (2390).—Hornblende-gneiss, north fac
boll; × 35.

Granular aggregate of sphene with iron-o
blende, felspar, and quartz are also present.

Plate XLII.

Fig. 1. Hornblende-gneiss (basic) × 22.

Fig. 2. Hornblende-gneiss. × 35.

PLATE XLIII.

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1. (3409).—Epidote-amphibolite; × 35. Cnoc an Sgriodach, south of Loch nan Lub, near Stoer.

Hornblende, epidote, and felspar (andesine). The andesine and epidote form a saussuritic aggregate. See page 57.

2. (2415).—Zoisite-amphibolite; × 35. Lochan nam Breac Buidhe, Eireboll. Long, slender prisms of zoisite in a matrix of felspar. A pale-green hornblende is also present. See page 58.

Plate XLIII.

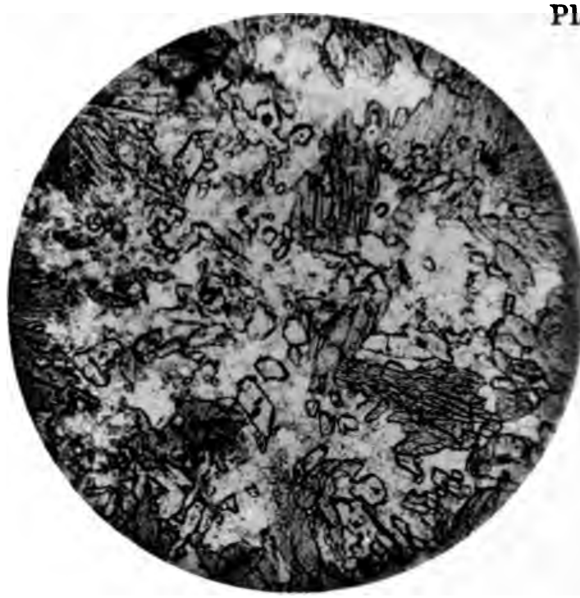


Fig. 1. Epidote - amphibolite. x 35.

Fig. 2. Zoisite - amphibolite. x 35.

PLATE XLIV.

---

1. (4461).—Hornblende-biotite-gneiss (modified pyroxene-gneiss); × 35. About 200 yards north-west of the bridge at Lochinver.

Green hornblende, reddish-brown biotite, plagioclase, quartz and iron-ores. The contrast between the biotite and hornblende is very marked in the section in consequence of the difference in colour; but this is of course lost in the photograph. The mode of occurrence of the biotite may, however, be easily recognised with a lens. See page 61.

2. (4461).—Portion of the same slide more highly magnified; × 60.

Hornblende, felspar, quartz and iron-ores. This photograph shows the peculiar character of the hornblende in this important group of rocks. The central portions of the aggregates, which probably represent original crystals of pyroxene, contain small and usually rounded grains of quartz; the marginal portions are composed of larger individuals which are not separated by quartz and which project into the surrounding felspar (andesine or labradorite). See page 61.

Plate XLIV.

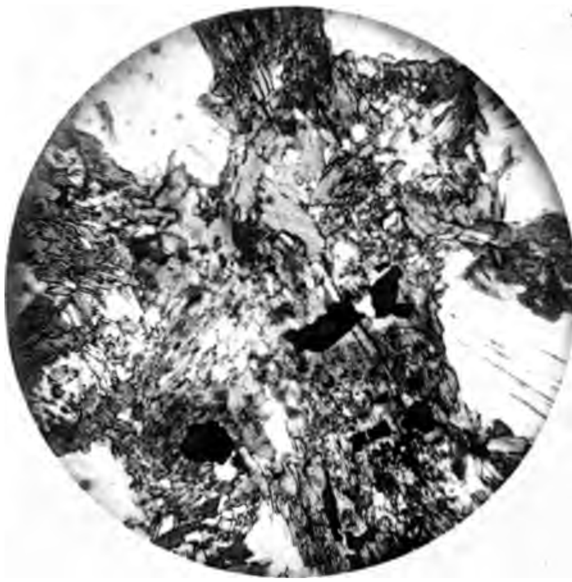


Fig. 1. Hornblende-biotite-gneiss. x 35.

Fig. 2. Hornblende-biotite-gneiss x 60.

PLATE XLV.

1. (3739).—Granulitic hornblende-gneiss.
east of Lochinver; × 35.

Ragged prisms of actinolite in a granulitic
epidote and biotite. Crystals of pyrite. Inclus
occur in the actinolite. See page 68.

2. (4454).—Granulitic hornblende-gneiss;
of Loch-na-h' Irinne, Clachtoll.

Hornblende, felspar, quartz and pyrite.
rock is in the form of grains. The felspar
distinguished. Both are water-clear and
same refractive index. They occur in grai
shape. See page 68.

Plate XLV.

Fig. 1. Granulitic hornblende-gneiss × 35.

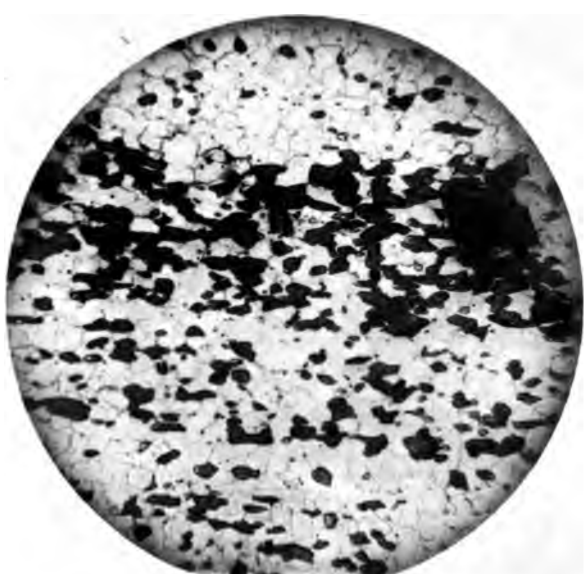


Fig. 2. Granulitic hornblende-gneiss. × 35.

PLATE XLVI.

1. (4454).—Roadside west from Loch-na-h' Irinne, Clachtoll, 4 miles north-west from Lochinver. Quartz-felspar mosaic in granulitic hornblende-gneiss; crossed nicols; × 35.

A portion of the same specimen as that represented in Plate XLV., fig. 2. This figure illustrates the fact that it is impossible to separate quartz from felspar under polarised light. See page 63.

2. (4454).—Same locality. Quartz-felspar mosaic. Another portion of the same specimen after treatment with hydrofluoric acid; × 35.

Quartz, felspar, and hornblende. The uncovered section has been treated with hydrofluoric acid and stained with fuchsine; but the greater part of the stain has been removed in order to render the felspar transparent. The quartz and felspar are not uniformly distributed. The quartz occurs in streaks and lenticles. This mode of distribution of the quartz and felspar is a necessary consequence of the fact that the granulitic hornblende-gneisses have been formed by the deformation of coarser-grained rocks. See page 65.

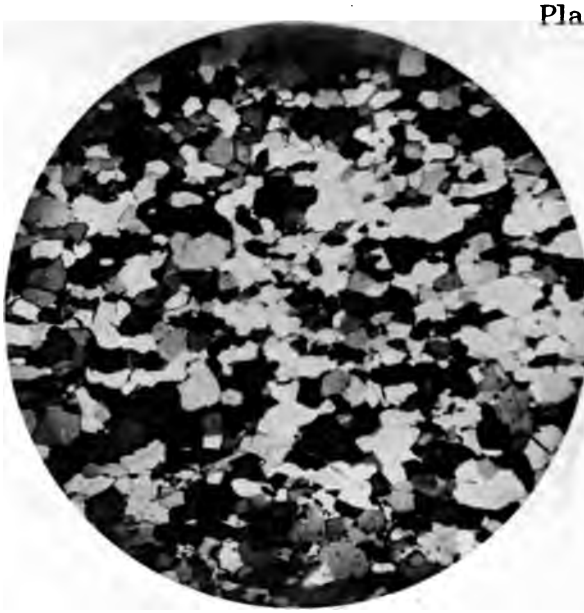


Fig. 1. Quartz - felspar - mosaic. × 35.

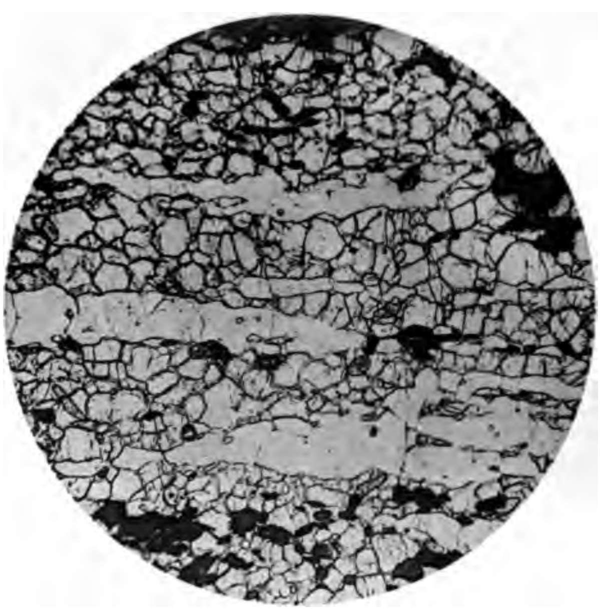


Fig. 2. Quartz - felspar - mosaic. × 35.

PLATE XLVII.

---

1. (8627).—Diabase. Hill-slope above lowest Chalda Loch, abou 1½ mile north-east of Inchnadamff; × 15.

Lath-shaped labradorite, augite and iron-ore. Green hornblend occurs as an accessory; a small patch may be recognised about half way between the centre and margin in a N.N.W. direction. Se page 91.

2. (2745).—Hornblende-enstatite-diabase. Quarter of a mile north west of Loch Chroisg, Assynt; × 35.

Lath-shaped labradorite, augite, enstatite and hornblende.

The central portions of the crystals of labradorite are turbid i consequence of the presence of minute inclusions. A large ophiti plate of enstatite, also containing inclusions, occurs on the north east margin, and a similar plate is seen near the centre on th south-east side. Ophitic green hornblende is represented to the wes and south-west of the centre. The dark patch on the west is als hornblende. The two sections of enstatite in the right half of th figure are separated by a large patch of augite. See page 92.

Plate XLVII.

Fig. 1. Diabase x 15.

Fig 2. Hornblende - enstatite-diabase. x 35.

PLATE XLVIII.

1. (2319).—Olivine-norite. North side of Loch Assynt, 4 miles west of Inchnadamff.

Olivine, enstatite, labradorite and iron-ores.

Olivine is represented on the left margin and at the top. It contains minute inclusions and anastomosing veins of magnetite. Enstatite is colourless and idiomorphic. The labradorite is interstitial. See page 92.

2. (2747).—Epidote-amphibolite (foliated). Quarter of a mile north-west of Loch Chroisg, Assynt; × 35.

Hornblende, felspar, epidote, sphene and iron-ores. The epidote and felspar form a saussuritic aggregate. The sphene forms granular, colourless aggregates surrounding the iron-ore. See page 94.

Plate XLVIII.

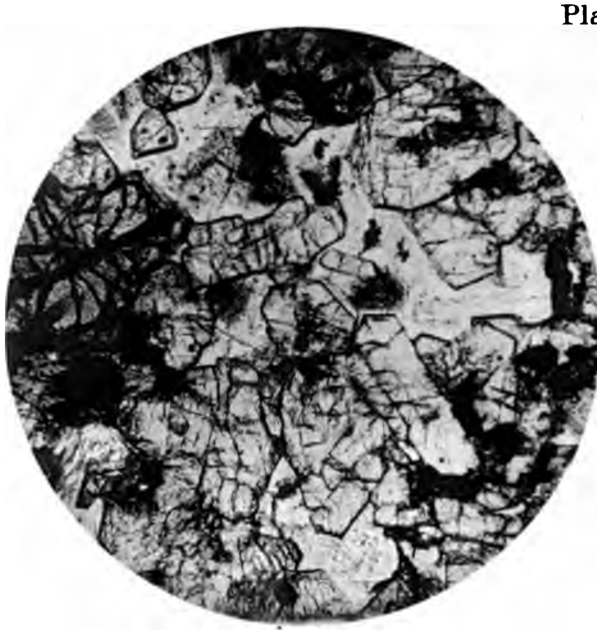


Fig. 1. Olivine - norite. × 35.

Fig. 2. Epidote-amphibolite. × 35.

PLATE XLIX.

1. (4434).—Hornblende-schist. $\frac{5}{8}$-mile north of Meall an Spardai[n] about $3\frac{1}{4}$ miles south of Poolewe; × 15.

The section is at right angles to the direction of linear foliatio[n]. Hornblende, felspar and quartz. The sections of hornblende a[re] almost all approximately at right angles to the vertical axis, an[d] there is no tendency to elongation in any special direction either i[n] the hornblende or felspar. See page 97.

2. (4434).—Section from the same specimen parallel to the line[ar] foliation; × 15.

The sections of hornblende are almost all approximately parallel [to] the vertical axis, and the individuals are elongated in this directio[n]. See page 97.

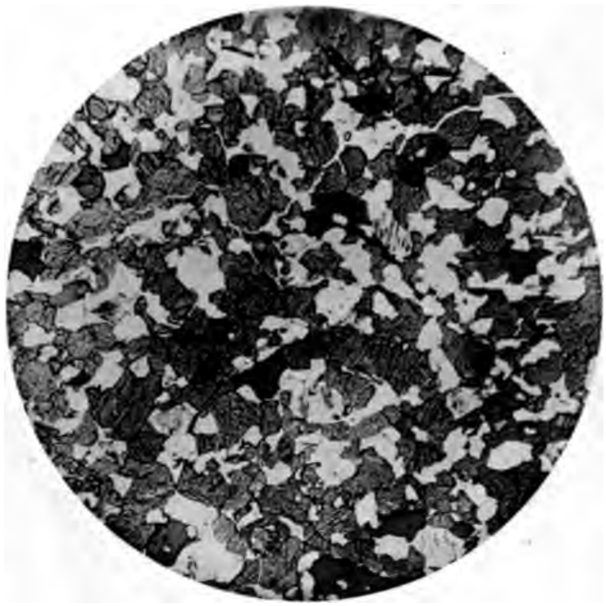


Fig. 1. Hornblende-schist × 15.

Fig. 2. Hornblende-schist × 15.

PLATE L.

1. (3894).—Chert pebble from Torridon Sandstone. Ben More, Coigach, Ross-shire. For description see page 280.

2. (6352).—Jasper pebble from the Torridon Sandstone. Cape Wrath. For description see page 280.

Plate L.

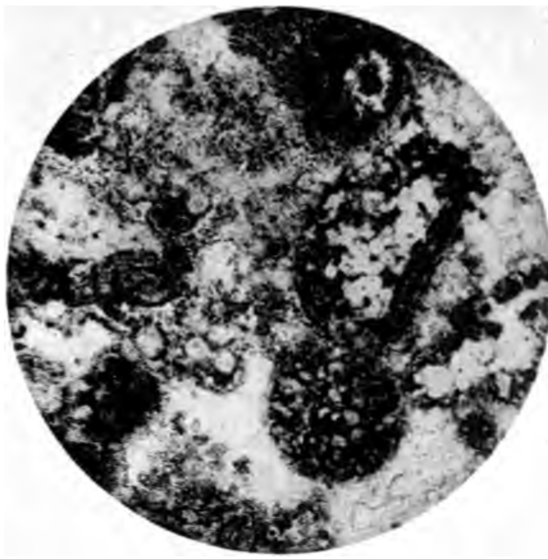


Fig. 1. Chert. x 30.

Fig. 2. Jasper. x 30.

PLATE LI.

1. (6189).—Spherulitic Felsite. Pebble from the Torridon Sandsto[n]
Applecross. For description see page 281.

2.—Spherulitic Felsite; another portion of the same slide.

Plate LI.

Fig. 1. Spherulitic Felsite. × 30.

Fig. 2. Spherulitic Felsite. × 30.

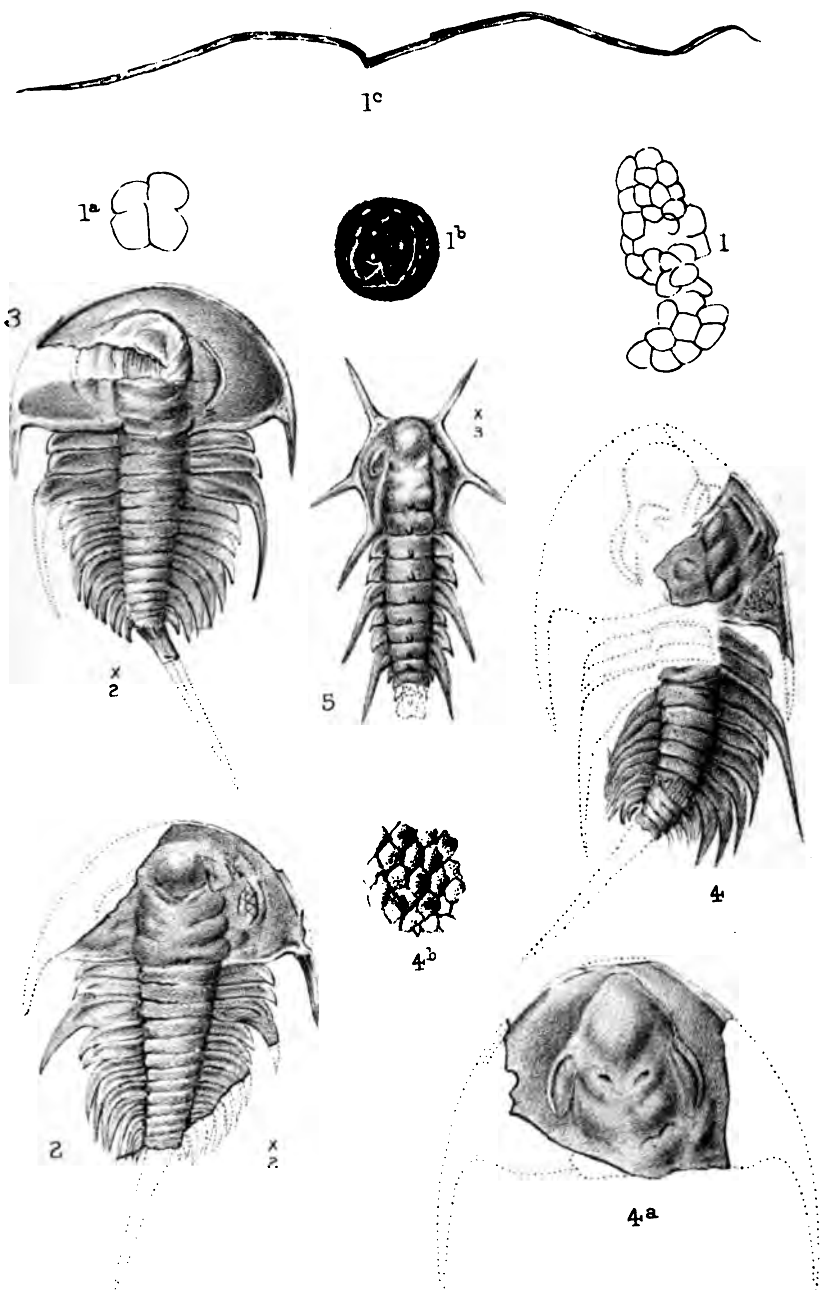
PLATE LII.

The figures 1, 1a, 1b, 1c represent traces of supposed organisms in phosphatic nodules from the Upper Torridon shales of Cailleach Head, Loch Broom; magnified about 60 diameters. See page 288.

1.	Irregular mass showing cellular structure.		
1a.	Group of four cells.		
1b.	Black sphere with perforations.		
1c.	Brown fibre.		
2.	Olenellus Lapworthi, *Peach*.	Enlarged 2 diameters.	
3.	,, ,, var. elongatus, *Peach*.	,,	
4.	,, reticulatus, *Peach*.	Natural size.	
4a.	,, ,, ,,	,,	
4b.	,, ,, ,,	Test enlarged to show nature of ornamentation.	
5.	Olenelloides armatus, *Peach*.	Enlarged 4 diameters.	

Figs. 2–5 from "Fucoid beds," Cambrian, Meall a' Ghiubhais, Kinlochewe, Ross-shire. Copied by permission of the Geological Society from Quart. Jour. Geol. Soc., Vol. L., 1894. Pls. XXIX., XXX., XXXI., and XXXII., pp. 674, 675.

PLATE LII.



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